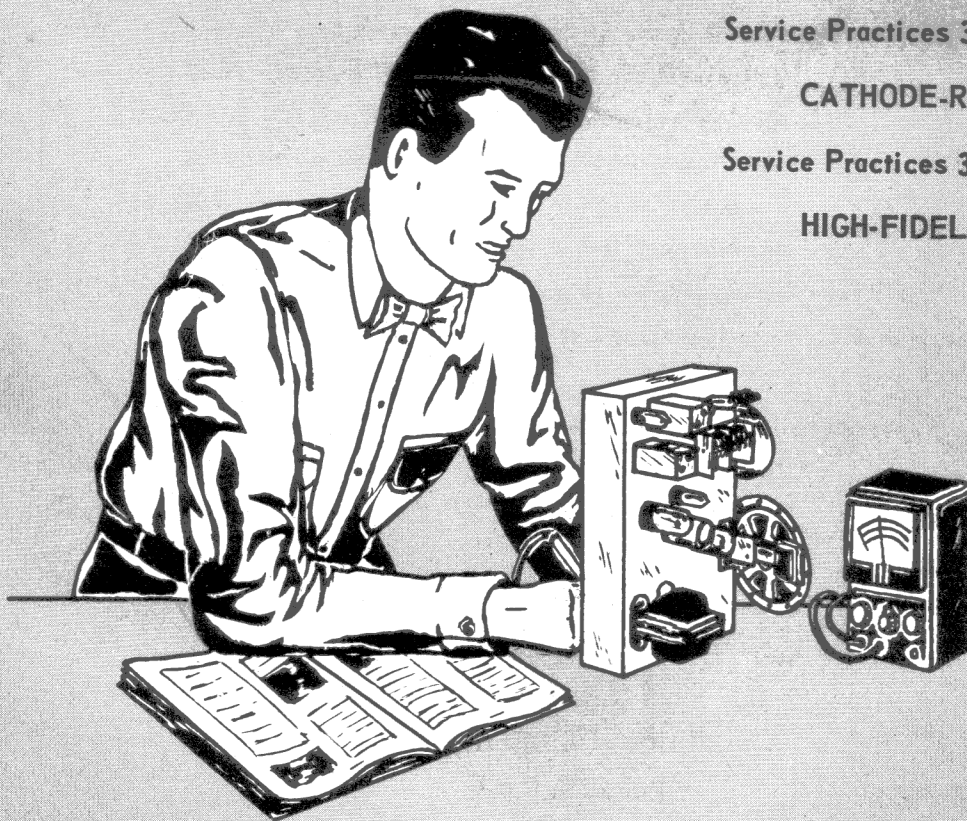


ELECTRONIC FUNDAMENTALS



Service Practices 33:

CATHODE-RAY OSCILLOSCOPE II

Service Practices 34:

HIGH-FIDELITY

RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York.

N. Y.



ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 33

CATHODE - RAY OSCILLOSCOPES II

- 33-1. Front Panel Controls, Switches, and Terminals**
- 33-2. Setting Up Oscilloscopes for Operation**
- 33-3. Using Oscilloscope To Measure Voltages**
- 33-4. Oscilloscope Tests For Audio Amplifiers**
- 33-5. Oscilloscope Tests For AM Receivers**
- 33-6. Oscilloscope Tests For FM Receivers**
- 33-7. Determining Frequency of an Unknown Signal**
- 33-8. Measuring Impedance of Audio-Frequency Components**
- 33-9. Oscilloscope Probes**
- 33-10. Precautions To Observe In Using Oscilloscopes**



RCA INSTITUTES, INC.
A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL
350 West 4th Street, New York 14, N. Y.

Service Practices 33

INTRODUCTION

The oscilloscope may be used (in conjunction with other test equipment) for trouble shooting many varieties of AM and FM receiver trouble; for checking audio amplifiers and tuners; and for the alignment of tuned stages in AM and FM sets. The procedures used in such tests will be described in this lesson.

33-1. FRONT PANEL CONTROLS, SWITCHES, AND TERMINALS

The front panel of a representative oscilloscope, the RCA WO-88A intended for use by radio-TV technicians is illustrated in Fig. 33-1. Let's go over the functions of these controls.

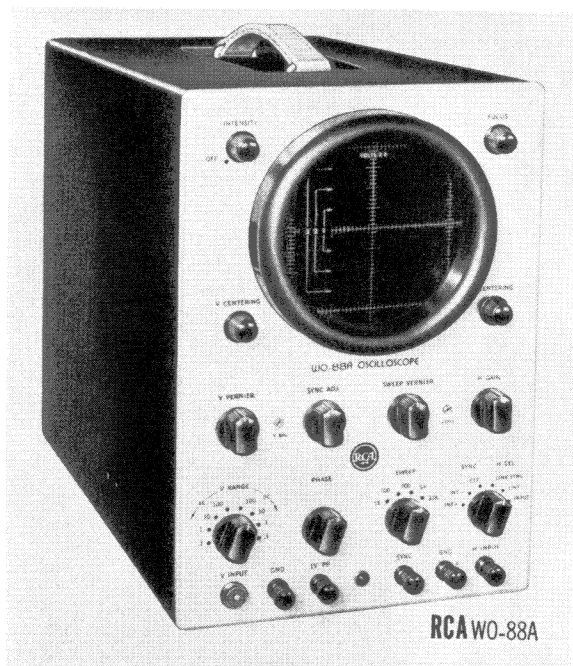


Fig. 33-1

OFF INTENSITY Control. The OFF INTENSITY control has two parts — an off-on switch and a potentiometer used to regulate the brightness of the trace by varying the bias of the cathode-ray tube. The switch and the potentiometer generally use the same shaft, just as in the case of the off-on switch and the volume control of a radio receiver. The switch is in series with the primary of the power transformer. At the extreme counter-clockwise setting of the shaft, the power is off, and no power is applied to the oscilloscope. When the control shaft is rotated clockwise, the switch is turned on and power is applied to the oscilloscope. The pilot light goes on, indicating that line voltage is being applied to the power supply. As the shaft is rotated clockwise, the resistance of the potentiometer portion of the OFF INTENSITY control is reduced. The bias on the cathode is reduced and the electron beam in the CRT becomes dense enough to produce a bright trace on the screen.

FOCUS Control. The FOCUS control is a potentiometer that regulates focusing by varying the d-c voltage applied to the focus electrode in the CRT. It is set to produce the sharpest possible waveform on the screen. When focusing is improper, the waveform will be blurred or fuzzy and evidences of abnormality will be hard to detect. A blurred trace will also make an accurate measurement of the waveform amplitude difficult or impossible.

The FOCUS control setting generally has to be readjusted when the setting of the intensity control is changed.

V CENTERING and H CENTERING Controls. The centering controls vary the d-c voltages applied to the deflection plates, shifting the starting position of the scanning

spot and, therefore, the entire trace. The V CENTERING (vertical centering) control moves the trace up and down. The H CENTERING (horizontal centering) control moves it from side to side. The adjustment range of the controls is great enough to move the scanning spot completely off the screen.

The centering controls are called positioning controls on some oscilloscopes. In others, they are called X position and Y position controls; the letter Y means *vertical*; the letter X means *horizontal*.

SWEEP and SWEEP VERNIER Controls.

Two controls are used for regulating the frequency of the horizontal sweep. One labelled SWEEP in Fig. 33-1 controls the frequency in large steps. In other oscilloscopes, this control is called the Sweep Selector, or Coarse Frequency. The other control, labelled SWEEP VERNIER in Fig. 33-1, varies the frequency range between the steps of the first control. Since this second control is capable of changing the frequency continuously (rather than in abrupt steps), and does so over a relatively small frequency range, it is often called a fine frequency control.

The SWEEP control is first set to *approximately* the proper frequency — that is, a frequency as close as possible to the frequency of the signal applied to the vertical input terminals. The fine frequency control is then adjusted till the exact number of waveforms required is produced on the screen, and the movement of these waveforms is minimum.

When the setting of the SWEEP control is too low, causing frequency of the time base generator in the oscilloscope to be much

less than that of the signal applied to the vertical input terminals, no waveforms will be distinguishable on the screen; the image will be a blur (Fig. 33-2a). If the setting of the coarse frequency control is low, but not extremely low, several cycles of vertical signal will be visible, permitting an easy inspection of the waveform shape (Fig. 33-2b). If the setting of the coarse frequency control is too high, fractional parts of one cycle of the vertical signal will be seen on the oscilloscope screen (Fig. 33-2c).

V RANGE and V VERNIER Controls. In some oscilloscopes, a vertical step attenuator is used. This switch-type control is labeled V RANGE in the oscilloscope illustrated in Fig. 33-1. In others, it is called the vertical attenuator, or vertical input control, or something similar. The function of the control is to attenuate or reduce large a-c voltages applied to the vertical input of the oscilloscope, to keep the waveform from being deflected off screen as well as to prevent overloading of the vertical input stage.

The vertical attenuator commonly reduces input voltages in multiples of 10. In the oscilloscope we have been considering, there is no attenuation at the 0.1 setting of the switch. At the 1 setting, the signal is reduced to 1/10 its value; at the 10 setting, it is reduced to 1/100 its value; at the 100 setting, it is reduced to 1/1000 of its value. In other oscilloscopes, the same settings may correspond to different values of attenuation. In still other oscilloscopes, different settings may be used for the same values of attenuation. The setting with the lowest numerical value is the setting for no attenuation. The attenuator should be set so that

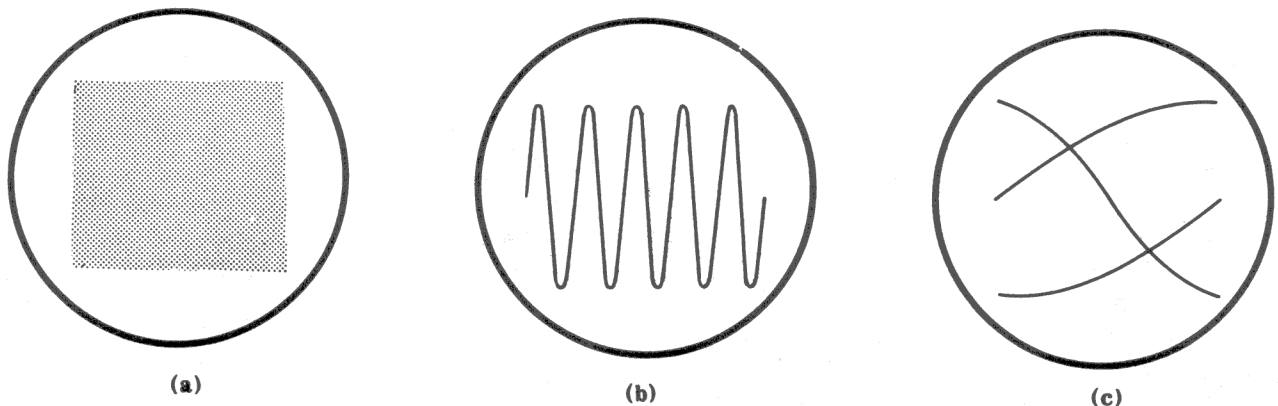


Fig. 33-2

the waveform occupies a little more than $\frac{1}{2}$ the height of the screen.

The control marked V VERNIER is also called the vertical gain or Y amplitude control by different oscilloscope manufacturers. Other names are assigned to it as well. The control is a continuously variable one that varies the vertical gain between attenuator steps. The waveform may be adjusted to the exact height required by setting the V RANGE control to the setting where the waveform is at a height as close as possible to the one desired and then setting the V VERNIER control so that the exact height desired is produced. Sometimes only a V RANGE control is provided.

In the oscilloscope shown in Fig. 33-1, the vertical attenuator (V RANGE) control is capable of varying the amplitude of applied d-c as well as a-c voltages. The settings at the left are for the attenuation of a-c voltages; those at the right are for reducing d-c or very low-frequency a-c input voltages.

Input Connections; Input Leads. The vertical input of the oscilloscope is in some cases connected to a jack on the front panel, as it is in the V INPUT jack on the oscilloscope we are discussing (Fig. 33-1). An oscilloscope cable that terminates in a connector that mates with the jack is used in this instance. In other instances, the vertical input is a terminal post, similar to the terminal post commonly used for the horizontal input (labeled H INPUT in Fig. 33-1). A coaxial cable commonly terminating in phone tips or alligator clips, or (less preferably) a pair of unshielded leads, connects between the vertical input and ground posts in such cases. For simplicity's sake, we will refer to both the coaxial cable and the unshielded leads as oscilloscope leads. The probe and cable assembly used for the oscilloscope under discussion serve the same purpose as the oscilloscope leads just described. A ground lead is used in conjunction with the probe to connect the oscilloscope vertical input to the receiver circuit under test.

When an a-c signal is to be measured in a conventional manner, the oscilloscope leads are connected to the V INPUT and GND jacks at one end; the other ends of the

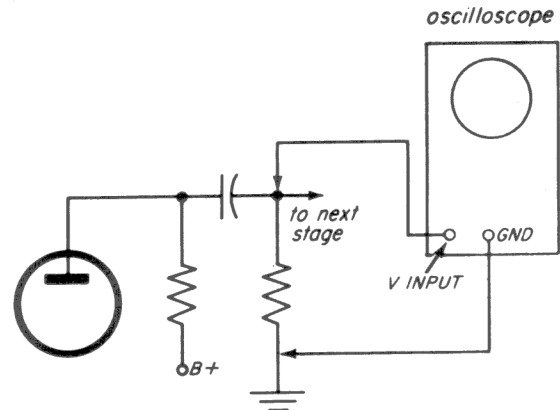


Fig. 33-3

leads go to the circuit to be tested (Fig. 33-3). That is, they connect to the circuit point to be checked and chassis in the same way that a voltmeter would be connected to the circuit.

The probe and cable assembly used for the oscilloscope under discussion are illustrated in Fig. 33-4. Alligator clips are inserted over the end of the probe and ground lead so that they can be connected to the circuit. The probe is called a *direct probe*, because it has no components in it for isolating or demodulating purposes. The reason it is added to the vertical input cable is that it permits the fast attachment of a low-capacitance or demodulator probe. In order to attach a demodulator probe, remove the alligator clip from the tip of the direct probe and place the low-capacitance or demodulator probe over the tip.

Coaxial cable is used with the probe because it shields the vertical input lead against stray hum fields. The inner conductor of the cable connects the vertical input of the oscilloscope to the circuit point

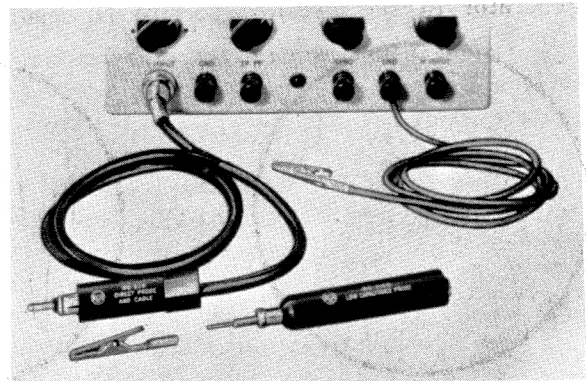


Fig. 33-4

to be checked; the outer conductor or shield of the cable connects to oscilloscope ground.

Both the vertical input cable just described and the oscilloscope leads shown in Fig. 33-4 are made of coaxial cable. However, the oscilloscope leads, which are commonly used, have no direct probe and terminate in phone tips or alligator clips instead of in a jack. Furthermore, unlike the probe and cable assembly, the oscilloscope leads have their outer shields connected to chassis. The difference in shielding that results is not significant.

Sometimes unshielded leads are used, but such leads may be the reason for undesired vertical deflection as a result of stray pick-up.

H INPUT Terminals. In certain applications of the oscilloscope, the horizontal time-base generator is disconnected from the horizontal amplifier, and an external source of horizontal deflection voltage is fed to the horizontal input of the oscilloscope. Connection to the horizontal input is made at the terminal labeled H INPUT in the oscilloscope shown in Fig. 33-1. In some oscilloscopes, the terminal is called the X input.

External sweep is commonly used when a sweep generator is employed in conjunction with an oscilloscope to align a radio (or television) receiver. The reason for this is that a *sine-wave* (not *sawtooth*) horizontal sweep voltage is needed to properly reproduce the sweep generator output signal.

SYNC H SEL Switch. The sync selector switch (labeled SYNC H SEL in Fig. 33-1) makes a number of different sync signals available. When the setting of the switch is at INT (abbreviation for *internal*), a portion of the vertical amplifier output signal is fed back to the oscilloscope time-base generator, and synchronizes the applied a-c signal. This switch setting is the most commonly used one.

On the oscilloscope shown in Fig. 33-1, two INT settings, INT+ and INT−, are provided to ensure good lock-in action. This

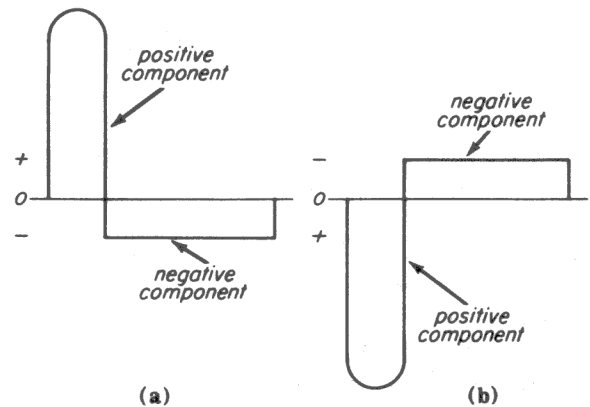


Fig. 33-5

lock-in action depends upon the amplitude of the positive peak of the sync signal. If the positive peak of the sync signal is high enough to trigger the time-base generator or regulate its frequency (Fig. 33-5a), proper synchronization will occur. For signals of this type, the INT+ setting should be used. But certain signals (found mostly in television receivers) may have a polarity such that the tall peak is negative. The positive peak is not high enough in amplitude to trigger the time-base generator. However, by setting the switch to the INT− position, the polarity of the applied vertical signal can be reversed. Then the tall peak will be positive, and proper lock-in will occur. This reversal of phase can be accomplished by taking the sync signal from a circuit point other than the vertical amplifier plate circuit — say, the cathode circuit, where the signal is 180 degrees out of phase with the signal at the plate.

Provision of INT+ and INT− settings (also labeled int pos and int neg in some oscilloscopes) is a refinement useful chiefly in television receiver servicing. For the general run of work, you will do in radio, it will make no difference which INT setting the selector switch is placed at.

The setting labeled LINE SYNC (Fig. 33-1) may be used when the frequency of the signal applied to the vertical input is 60 cps, or a multiple or submultiple of 60 cps. (A *multiple* of 60 cps is a frequency that is twice, or three times, or four times 60 cps, etc. — for instance, 120, 180, or 240 cps. A *submultiple* of 60 cps is a frequency that is 1/3, or 1/2, or 1/4 of 60 cps, etc. — for instance, 20, 30 or 15 cps.) The time-base

generator of the oscilloscope must be set to a frequency of 60 cps or lower for synchronization to take place.

To find the frequency setting of the time-base generator, simply divide the *frequency of the applied signal* by the *number of waveforms seen on the screen*. If a 120-cps signal is being applied to the oscilloscope vertical input, and 3 waveforms are reproduced on the screen, the oscilloscope setting is $120/3$, or 40 cps. If 4 waveforms are seen, the oscilloscope frequency setting is $120/4$, or 30 cps, etc.

LINE SYNC should be used instead of INT sync when you expect to vary the level of applied signal during your tests. If the oscilloscope sync selector setting were at INT setting during such tests, the level of the signal taken off at the vertical amplifier for sync purposes would vary. A level of sync signal that was suitable with the vertical input signal at one amplitude might be inadequate or excessive with the vertical input signal at a different amplitude.

With the sync selector switch set to LINE SYNC, this difficulty is eliminated. The sync signal is derived from the line voltage at this setting, and is independent of the level of the applied vertical signal.

Another condition under which a LINE SYNC setting may be preferable to an INT setting is when a nonsinusoidal signal whose frequency is a multiple or submultiple of 60 cps is to be observed. The sine-wave 60-cps line signal will provide better synchronization than nonsinusoidal signals that have broader peaks.

The SYNC H SEL switch should be set to INPUT when the time-base generator is disconnected and an external source of sweep voltage is used for horizontal deflection. In some oscilloscopes, the coarse-frequency control has a setting at which the necessary circuit switching takes place. The setting is often labeled hor. input. In the oscilloscope shown in Fig. 33-1, the circuit switching referred to takes place when the SYNC H SEL switch is placed at INPUT setting. At this setting, the external sweep voltage

applied to the H INPUT terminal of the oscilloscope is connected to the input of the horizontal amplifier of the oscilloscope. In other oscilloscopes, suitable switch settings permit the external sweep voltage to be fed either directly, or through the oscilloscope horizontal amplifier, to the horizontal deflection plates.

At the LINE setting of the SYNC H SEL switch, the output of the time-base generator is disconnected from the horizontal amplifier, and a 60-cps *sine-wave* signal derived from the line is fed to the horizontal amplifier in its place.

A 60-cps sine-wave signal is generally needed for horizontal deflection in the oscilloscope when a sweep generator is used in conjunction with the oscilloscope. The required sine-wave voltage is usually made available at terminals on the front panel of the sweep generator. Leads from these terminals connect to the horizontal input of the oscilloscope.

The oscilloscope itself may also provide a 60-cps sine-wave sweep. The instrument we are considering does. In such a case, it is not necessary to connect leads between the sweep generator terminals at which a sine-wave deflection voltage is provided and the horizontal input terminals of the oscilloscope. In some bench set-ups, where an oscilloscope is in constant use, the fewer the connections that must be made between the oscilloscope and other equipment, the faster is the servicing procedure.

The EXT (external) setting of the SYNC H SEL switch, which makes external sync available, is useful when a signal to be observed on the oscilloscope is applied directly to the vertical deflection plates. Since the vertical amplifier is not used, a signal sync must be provided from an outside source.

The EXT setting is also used to provide external sync when the amplitude of the vertical input signal varies rapidly. Use of an external sync signal provides a sync that is relatively free of amplitude changes, so it is not necessary to adjust the SYNC ADJ. control very often. The SYNC ADJ. control

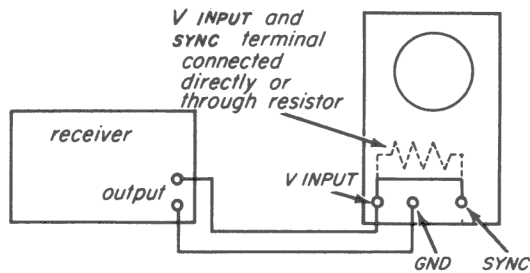


Fig. 33-6

regulates the amplitude of the sync signal fed to the time-base generator.

The EXT setting is also used when an external source of horizontal deflection voltage is used. External synchronization is necessary in such a case, since the internal sync signal from the oscilloscope can be fed only to the time-base generator of the oscilloscope and not to the external source of horizontal deflection voltage being used.

Connections of a receiver to the oscilloscope when an external sync signal is to be used are illustrated in Fig. 33-6. The output of the receiver stage under test feeds to the vertical input of the oscilloscope; the output of the stage also connects, in parallel, to the sync terminal on the oscilloscope.

If the waveform seen on the screen is affected by the connection of the receiver to the sync terminal, the sync circuit in the oscilloscope is probably loading down the receiver circuit. To minimize such loading, insert an isolating resistor of between 100,000 and 250,000 ohms in value between the vertical input and sync terminals of the oscilloscope. The resistor will reduce the sync voltage applied to the oscilloscope. If the signal level at the receiver stage is not high enough for such a reduction to be tolerated — that is, if insufficient sync signal is fed to the oscilloscope because of the insertion of the resistor — the use of external sync may not be feasible.

SYNC ADJ. Control. The control labeled SYNC ADJ. in the oscilloscope we are considering is also called *Sync Vernier*, *Sync Amplitude*, or is given some similar sounding name by oscilloscope manufacturers. The control is used to regulate the amount of sync voltage fed from the vertical amplifier to the input of the time-base generator.

The setting of the control should be kept as low as possible. If the control setting is advanced beyond a certain point, an excessive sync voltage will be fed to the grid of the time-base generator. The change in bias that results will make the horizontal sweep nonlinear, causing the waveform reproduced on the oscilloscope screen to be distorted. The number of waveforms seen on the screen will change when the sync control is turned up too far, since the time-base generator frequency rises. Therefore, retrace will be earlier.

To adjust the SYNC ADJ. correctly, set the sweep and sweep vernier controls to the point where the image seen on the screen is almost stationary. Then advance the sync control just enough to completely stop the movement of the image on the screen.

H GAIN Control. The control labeled H GAIN regulates the amplitude of the horizontal deflection signal. The control is capable of varying the waveform image from an image so narrow that it is a straight vertical line, to one so wide that its outer portions fall off screen.

It is useful to have the waveform in the form of a vertical line when the voltage of the waveform is to be measured. In such a case, the horizontal sweep can be reduced to zero by setting the H GAIN control to its extreme counterclockwise position. Conversely, sometimes it is useful to have the waveform very wide. A small section of a waveform must be carefully observed. Expanding the horizontal sweep to maximum will spread out the waveform horizontally on the screen. For instance, if three waveforms are on the screen, advancing the horizontal gain control to maximum will spread the center waveform enough to make any abnormality readily visible. The fact that the other two waveforms may deflect off screen as a result of this adjustment is not important, since the formation they contain is duplicated in the center waveform.

PHASE Control. The PHASE control is used chiefly when a sweep generator and oscilloscope are used for the alignment of a radio or television receiver. Under such

conditions, a sine-wave sweep generally has to be used for horizontal deflection in the oscilloscope. If the sine-wave sweep comes from the sweep generator, the PHASE control on the oscilloscope is not used. However, the PHASE control may be used when the oscilloscope itself provides the 60-cps sine-wave horizontal sweep. The oscilloscope beam, in other words, reproduces the waveform during trace and retrace (unless the retrace is blanked out). If the phase of the sweep generator signal applied to the vertical input of the oscilloscope is the same as the phase of the 60-cps sine-wave voltage producing horizontal deflection in the oscilloscope, the waveforms produced during trace and retrace will coincide, and only one waveform will be seen. If the phasing is incorrect, a double trace will be visible (see Fig. 33-7a). Adjustment of the phase control permits the two traces to be superimposed over each other, so that only one waveform is seen (Fig. 33-7b). A double waveform is as undesirable as a ghost (double picture) on a television screen.

The PHASE control is also useful when the SYNCH SEL switch is in the LINE SYNC position. At this setting, a 60-cps line signal is used to sync the horizontal sawtooth sweep of the oscilloscope. Adjustment of the PHASE control will permit the phase of the waveform seen on the screen — i.e., its starting and finishing points — to be shifted, making possible a more accurate check of some portion of the waveform.

1V PP Test-Signal Terminal. A 1-volt peak-to-peak voltage is made available between the 1V PP terminal and the GND terminal. This voltage is used to calibrate the oscilloscope for a-c voltage measurements. In other oscilloscopes, the value of the calibrating voltage available at the test signal terminal may be 3-volts peak-to-peak, 18-volts peak-to-peak, or some other value.

GND Terminals. The terminals marked GND in the oscilloscope illustrated in Fig. 33-1 are directly connected to the chassis of the oscilloscope. They serve as a common ground for the oscilloscope and the receiver chassis to be tested, or for the oscilloscope and any test instrument that is connected to the oscilloscope.

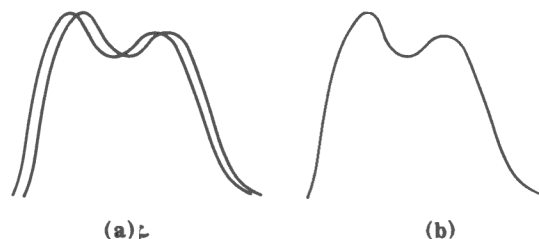


Fig. 33-7

Intensity Modulation Terminal. In some oscilloscopes, a terminal labeled intensity modulation or beam modulation is employed. This terminal, labeled BEAM MOD in Fig. 33-8, connects to either the grid or cathode of the CRT and permits a signal to be applied to either one or the other of these electrodes. As a result, the electron beam can be made to vary in intensity (become brighter and darker) in accordance with the amplitude variations of the signal applied.

For some tests, an external voltage is applied between the BEAM MOD terminal and ground. One such test permits a signal of an unknown frequency to be identified.



Fig. 33-8

Another makes possible the detection of a phase difference between two signals.

33-2. SETTING UP OSCILLOSCOPES FOR OPERATION

The procedure described below will give you an idea of how a typical oscilloscope, such as the one shown in Fig. 33-1, is set up. However, the procedure outlined applies in general to oscilloscopes intended for radio-TV service work. It will have to be modified slightly, depending on the controls and circuits used in the oscilloscopes you are using. If you buy an oscilloscope, the instruction manual that comes with it will tell you the exact procedure to follow.

Setting Up the Oscilloscope To Observe Shape of Waveform. If you want to observe the shape of a waveform and you're not concerned with the amplitude of the waveform, make the following adjustments:

1. Set the FOCUS, H CENTERING, and V CENTERING controls to the centers of their respective ranges.

2. Place the SWEEP control at a low-frequency setting — i.e., one close to the extreme counterclockwise position.

3. Set the SYNC H SEL switch to INT-or INT+.

4. Rotate the SYNC ADJ. control to its extreme counterclockwise setting.

5. Advance the H GAIN control to 3/4 of its fully clockwise setting.

6. Turn on the oscilloscope by turning off the INTENSITY control clockwise until a click is heard. Allow about 30 seconds for the instrument to warm up. Then turn up the INTENSITY control, rotating it clockwise until a horizontal line becomes visible on the screen. Center the line on the screen by appropriate readjustment of the V CENTERING and H CENTERING controls.

7. Adjust the FOCUS control to make the trace as clear and sharp as possible. If the trace isn't bright enough, turn up the IN-

TENSITY control a bit further. Then re-adjust the FOCUS control once more for best clarity. Keep in mind that the INTENSITY and FOCUS controls affect each other; it is usually necessary to readjust one when the other has been reset.

8. Turn up the VERNIER control to approximately 1/3 of its maximum clockwise setting.

9. Set the V RANGE switch for minimum attenuation. In the oscilloscope under consideration, this setting is .1. It is better to use the AC setting so as to avoid the need to readjust the V CENTERING control.

10. Apply the signal to be observed to the V INPUT terminal of the oscilloscope. Do this by connecting the input cable and ground lead to the circuit under test. Turn the receiver on and let it warm up for a minute or so. If the stage to whose output the oscilloscope cable is connected is passing a large enough signal, an image of some kind will be seen on the oscilloscope screen.

If the image resembles either of these, shown in Fig. 32-2a and b, the SWEEP control setting is too low, and should be advanced to the point where recognizable waveforms are seen on the screen. If the image looks like the one shown in Fig. 32-2c, the SWEEP control setting is too high; the SWEEP control should be set to a lower frequency, to produce recognizable waveforms on the screen.

If the amplitude of the waveform is too high or too low, readjust the V VERNIER and/or V RANGE controls until the waveform image occupies approximately half the height of the screen.

When waveforms of the desired amplitude have been obtained, set the SWEEP and SWEEP VERNIER controls to the point where three signal cycles are produced. Reset the SWEEP VERNIER so that the waveform drift across the screen is minimum.

11. Advance the SYNC ADJ. control to the point where the waveforms just become stationary. Do not advance the control any

further. The number or shape of the waveforms originally seen on the oscilloscope screen should not change when the SYNC ADJ. control is advanced unless it is advanced too far.

33-3. USING THE OSCILLOSCOPE TO MEASURE VOLTAGES

Although the oscilloscope is capable of measuring a-c voltages, a-c with a d-c component, and d-c voltages, it is more practical to use it for making measurements for which ordinary voltmeters are not suited. Therefore, oscilloscopes are used for measuring high-frequency a-c voltages, signal voltages of low amplitude, a-c voltages in circuits with a high impedance, and a-c voltages whose shape is of interest to the serviceman. As a rule, oscilloscopes are not used for measuring such voltages as the 60-cps heater voltage, which can easily be measured with an a-c voltmeter.

A-C Voltage Measurement. To measure an a-c voltage of an unknown amplitude, the deflection such a voltage produces on the oscilloscope screen must be compared with the deflection produced by a voltage of a *known* amplitude. The known voltage is called a *calibrating voltage*. A calibrating voltage is often provided in the oscilloscope itself; a source of calibration voltage outside the oscilloscope may also be used. In the case of the oscilloscope, we are considering, a test signal of 1 volt peak-to-peak is made available on the front panel.

The following procedure is employed in calibrating the RCA WO-88A oscilloscope.

1. Adjust the controls of the oscilloscope so that a horizontal line is produced on the screen.

2. Connect the oscilloscope cable to the V INPUT and the ground lead to the GND terminal.

3. Set the V RANGE to position 1 on the AC half of the range settings. When the frequency of the vertical signal is very low, — say 30 cps or less — setting the V RANGE switch to position 1 on the DC half of the range will provide more accurate results.

4. Connect the probe tip of the oscilloscope cable to the 1V PP terminal. Adjust the V CENTERING control so that the waveform is centered and adjust the V VERNIER control until the waveform on the screen is exactly 1 inch high. Heights of 1, 2, and 3 inches respectively are marked off at the left hand side of the screen (Fig. 33-1). One volt now covers 10 divisions on the vertical scale in the center of the screen. Therefore, each division on the vertical scale is equal to 0.1 volt.

5. Disconnect the probe tip from the 1V PP terminal. Do not change the setting of the V VERNIER control during the remainder of the voltage measurement. If you do, the calibration will be upset and your measurements will be inaccurate.

6. Connect the direct probe and the ground lead of the oscilloscope across the voltage in the receiver to be measured. Count the number of scale divisions across which the voltage extends from peak-to-peak, and multiply it by the value of one division — 0.1 volt. You will then have the peak-to-peak voltage of the signal. If the signal has an amplitude of 15 divisions, the peak-to-peak voltage is 15×0.1 or 1.5 volts; if the signal amplitude is 20 divisions, the peak-to-peak voltage is 2 volts etc.

If the voltage is large enough to deflect off screen with the V RANGE switch set to 1, change the setting of the V RANGE switch until the signal falls within the boundaries of the screen. Count off the number of scale divisions over which the signal extends in the vertical direction. Multiply this number by the original value of each division — 0.1 volt. Now multiply the total by the number indicating the setting of the V RANGE switch.

For instance, if the V RANGE setting is 10, and the signal has a height of 5 scale divisions, the signal amplitude is $5 \times 0.1 \times 10$, or 5 volts. If the V RANGE setting is 100, and the signal has a height of 10 scale divisions, the signal amplitude is $10 \times 0.1 \times 100$, or 100 volts.

The voltage measurement will be simplified if the H GAIN control is set to reduce the horizontal sweep to zero, thereby pro-

ducing a vertical line on the screen. The height of the line will be the same as the peak-to-peak height of the waveform originally on the screen. It is easier to measure the height of the line than the height of the spread-out waveform. By adjustment of the H CENTERING control, the line can be made to fall either between the 1-inch marks or on the vertical scale on the center of the screen. Besides, the vertical signal need not be locked into synchronization in the way that a spread-out waveform must be.

A similar calibration technique is used with most oscilloscopes. The differences in details depend upon the type of oscilloscope. For example, some oscilloscopes have their masks marked off in squares instead of in scale divisions. However, each square on such oscilloscopes is equivalent to a scale division on the oscilloscope we have been discussing. Other oscilloscopes do not have a vertical attenuator (V RANGE) switch. Such oscilloscopes must be calibrated by means of the vertical gain (V VERNIER) control alone.

Let's consider how the vertical gain control alone can be used for calibration. Assume that a test signal of 6.3 volts rms can be applied to the screen by means of a control on the front panel of the oscilloscope. The peak-to-peak value of this signal is approximately 2.8 times its rms value, or about 18 volts. We must use an approximate measurement rather than a definite one because the actual value of the signal, if it is derived from an unregulated heater-voltage supply (as it so often is), depends upon a varying line voltage.

By means of adjusting the vertical gain control, the 18-volt signal can be made to extend vertically over 18 divisions in the vertical scale in the center of the screen. As a result, each scale division can be made to stand for one volt. If there are 50 divisions on the vertical scale, the amplitude of voltages up to 50 volts can be read. Since there is no V RANGE switch, the value of each scale division cannot be multiplied so that higher voltages can be read. The only way to read higher voltages is to calibrate the oscilloscope again so that each scale division stands for a greater value. For example,

instead of spreading the 18-volt peak-to-peak voltage over 18 divisions on the vertical scale, it can be spread over only 9 divisions. Then each scale division has a value of 2 volts, and the values of voltages as high as 100 volts can be read on the screen.

The oscilloscope, without a V RANGE control, can be calibrated to read a still higher voltage by means of calibrating it with the line voltage. The nominal value of the line voltage is 117 volts rms. Its peak-to-peak value is approximately 330 volts. If 330 volts is applied to the vertical input of the oscilloscope, and made to cover 33 scale divisions, each division will count for 10 volts. If the oscilloscope has a total of 50 vertical divisions, a voltage as high as 500 volts can be measured.

This method can be made more accurate by measuring the line voltage with an a-c voltmeter and multiplying the value obtained by 2.8. The multiplier should really be 2.828, but 2.8 is close enough for our purposes. Suppose the line voltage measures 110 volts. The peak-to-peak value of this voltage is 308 volts, approximately. We can round this number off to 310 volts, to simplify our computation. Make this voltage occupy say 31 divisions. Each division will now count for 10 volts.

The method is still an approximate one, but it is somewhat more accurate than the one previously described.

But greater accuracy than this is not necessary for making radio and TV tests that require the determination of the amplitude of waveforms. For really accurate voltage measurements, the oscilloscope must provide an accurate calibrating voltage, or an external unit called an *oscilloscope voltage calibrator* must be used to calibrate the oscilloscope.

Measurements of D-C Voltages. Although it is much simpler and faster to use a d-c voltmeter to measure d-c voltages, an oscilloscope can be used when a d-c voltmeter is temporarily out of order or an additional d-c voltmeter is needed.

If the oscilloscope has direct-coupled vertical amplifier stages, d-c voltage may be

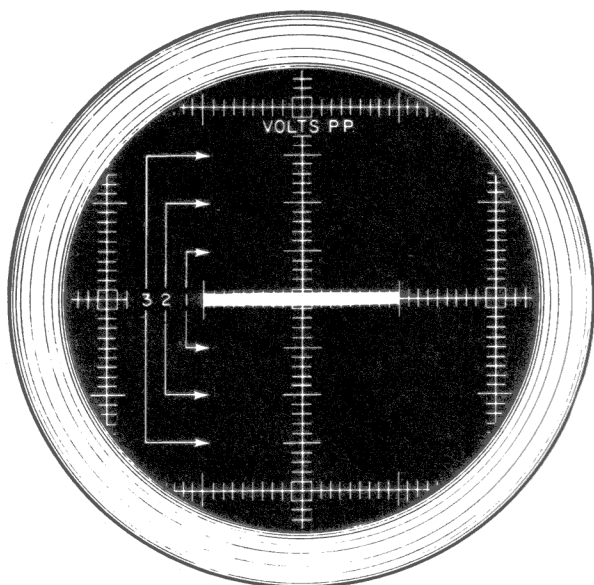


Fig. 33-9

applied to its vertical input. If an oscilloscope has a vertical amplifier section that uses resistance-capacitance coupling, a d-c voltage will not be permitted to pass through to the deflection plates; the d-c voltage must be applied directly to the deflection plates of the oscilloscope — usually, the vertical deflection plates. The RCA WO-88A uses a direct-coupled vertical amplifier section, and will readily measure d-c voltages.

A d-c voltage must be used for calibration purposes. The procedure is essentially the same as the one used for calibrating the oscilloscope for a-c voltage measurements.

If a low d-c voltage is to be measured, use a small d-c calibration voltage, supplied, for example, by a new *A* battery that is known to deliver 1.6 volts under no-load conditions. If a high d-c voltage is to be measured, the calibrating voltage should be a high d-c voltage whose value is known.

Before calibrating the oscilloscope, the trace should be vertically centered (see Fig. 33-9). This center position of the trace will now serve as the zero axis. When a d-c voltage is applied to the vertical input of the oscilloscope, the trace will deflect up or down, depending on the polarity of the voltage. The distance over which the trace is deflected is a measure of the voltage.

Suppose the trace line moves 5 scale divisions up (Fig. 33-10), and each division

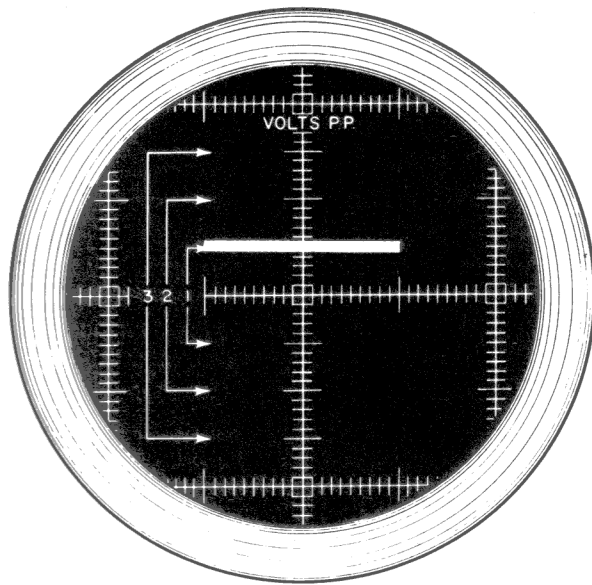


Fig. 33-10

has been made to count for 1 volt during the oscilloscope calibration. The voltage is 5 volts in this case.

When the oscilloscope vertical amplifier is not d-c coupled, the d-c voltage to be measured is applied to the vertical deflection plates. The deflection plates are disconnected from the amplifier, at the rear panel of the oscilloscope, as indicated in Fig. 33-11. (If the deflection plates are *not* connected to rear panel terminals, the method we are describing is not practical.) The calibrating voltage is then applied to the deflecting plates; the oscilloscope is calibrated; then the unknown voltage is connected and its value determined. Figure 33-11 illustrates the necessary changes in rear terminal connections in one make of oscilloscope. Only relatively large d-c voltages can be measured in this way; small voltages will not produce sufficient deflection on the screen.

Warning: The rear terminal connections to the deflection plates may be several hundred volts positive with respect to the oscilloscope case, in some instances. Turn power off before opening or remaking connections to avoid shock.

Measurements of A-C Voltage with a D-C Component. Some a-c voltages have a d-c level. For instance, the ripple voltage at the input of the filter of a power supply (Fig. 33-12) has both d-c and a-c components.

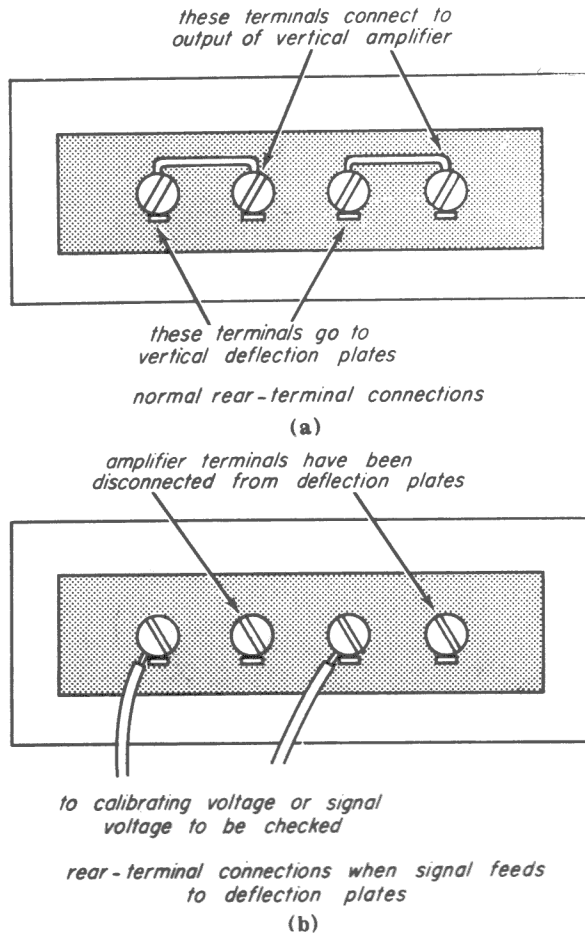


Fig. 33-11

If the waveform in Fig. 33-12 is applied to the vertical input of an oscilloscope set for an a-c voltage measurement, a waveform similar to the one shown in Fig. 33-13 will appear on the screen of the oscilloscope. The d-c level of the signal is missing in the waveform on the screen, because the coupling capacitor between the vertical input of the oscilloscope and the first vertical amplifier stage (as well as the other coupling capacitors in the vertical amplifier section) blocks the d-c voltage. If the d-c level were present, the waveform would be displaced above the center reference line.

In order to measure both the d-c and a-c component of the signal on the oscilloscope we just considered, the voltage must be applied directly to the vertical deflection plates. However, if an oscilloscope has a d-c coupled vertical amplifier, the d-c and a-c signal components can be observed by setting the oscilloscope up in the same way as for the display and measurement of a d-c voltage.

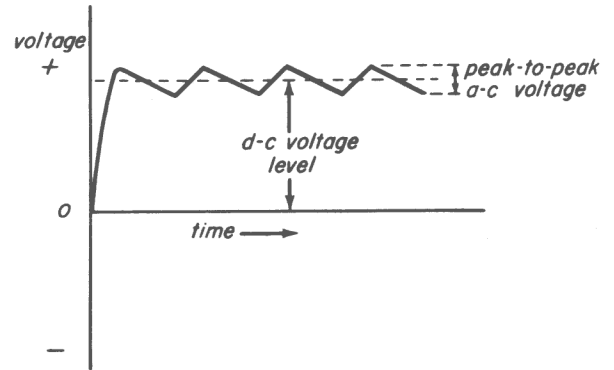


Fig. 33-12

Measuring Alternating Current with an Oscilloscope. Although servicemen seldom find it necessary to measure the current flowing in a circuit, alternating current can be indirectly measured with an oscilloscope. The following procedure may be used to measure alternating current.

Insert a resistor in series with the circuit to be tested. The value of the resistor should be very small compared with the value of the circuit resistance in series with it to avoid introducing an error in the operation of the circuit. Set the oscilloscope controls properly and connect the vertical input leads across the resistor. The waveform of the voltage developed across the resistor will be seen on the oscilloscope.

In a pure resistance, voltage and current are in phase. Therefore, the current through

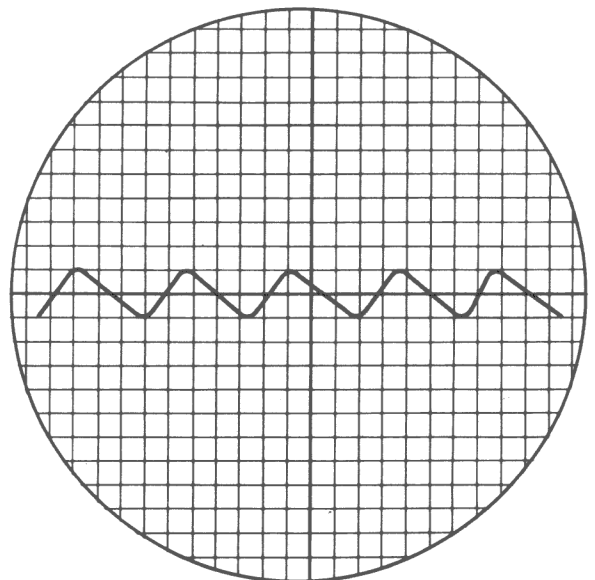


Fig. 33-13

the resistor is in phase with the voltage across the resistor; the current waveform will be the same in shape as the voltage waveform.

Measure the a-c voltage drop across the resistor. Divide this peak-to-peak voltage by the value of the resistor to obtain the peak-to-peak current. If the voltage is 0.5 volts for instance, and the resistor is 10 ohms, the peak-to-peak current is $0.5 \div 10 = 0.05$ amperes, or 50 ma.

The minimum value of resistance that can be inserted in series with the circuit depends on the sensitivity of the oscilloscope. The smaller the resistor used, the smaller will be the voltage developed across it, and the more sensitive will the oscilloscope have to be to measure this voltage.

33-4. OSCILLOSCOPE TESTS FOR AUDIO AMPLIFIERS

The oscilloscope is well suited for testing the audio amplifiers with record-players, AM and FM tuners, tape recorders, PA systems and juke boxes, etc. as well as the audio amplifier stages of radios (particularly those employed in high-fidelity receivers).

Distortion Testing with Sine-Wave Input.

By sending a sine-wave signal through an amplifier by means of connecting an audio signal generator or the audio signal output of an r-f signal generator at the input and an oscilloscope at the output, amplitude distortion in an amplifier can be checked. If the output is not an amplified copy of the input, distortion is being introduced. Either a single stage or an entire amplifier can be checked in this way. The entire amplifier can be checked first; if a distorted waveform is obtained at the output of the last stage, tests of the individual stages should be made, by applying the audio signal to the input of a stage, and connecting the oscilloscope at the output.

The amplitude of the applied signal should be kept low, to avoid overloading an audio amplifier stage; the distortion produced by such overloading would not be due to a fault in the amplifier.

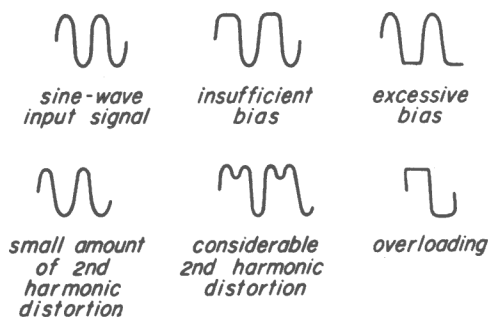


Fig. 33-14

A signal of any frequency in the audio bandpass of the amplifier may be used for this test. However, these are standard audio signals used for test purposes — 400 cps and 1,000 cps. All operative audio amplifiers will pass such signals.

No input signal other than the test signal should reach the input of the audio amplifier; if necessary, disconnect the input of the amplifier from the source of signal preceding it.

Some effects of distortion on a sine-wave input signal are illustrated in Fig. 33-14. You should become familiar with the normal distortion level of the equipment you are working on in order to be sure about what level of distortion is abnormal.

Lissajous Test for Amplitude Distortion.

A more sensitive test for distortion than the one just described may be made by forming a pattern on the oscilloscope known as a *Lissajous figure*. To do this, connect the audio signal source, audio amplifier, and oscilloscope as indicated in Fig. 33-15. The audio signal is applied to the input of the amplifier; it is also applied, in parallel, to the horizontal input of the oscilloscope. (The

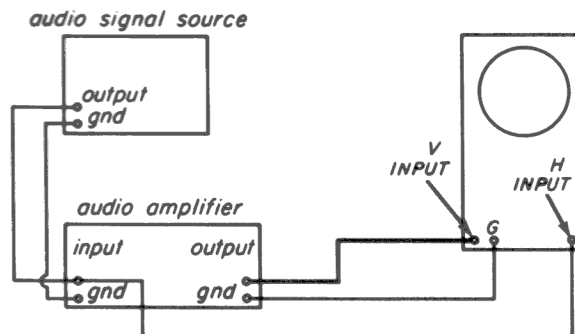


Fig. 33-15

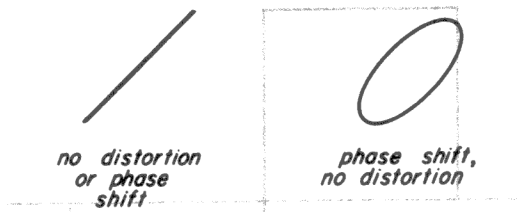


Fig. 33-16

time-base generator of the oscilloscope is not used during this test and should be switched off.) The output of the audio amplifier is applied to the vertical input of the oscilloscope.

If no amplitude distortion exists, the pattern seen on the oscilloscope will be either a diagonal line or an ellipse (see Fig. 33-16). A diagonal line will be seen if the signals fed to the horizontal and vertical inputs of the oscilloscope are in phase; an ellipse will be seen if the audio amplifier stage under test, or the vertical amplifier in the oscilloscope has shifted the phase of the signal passing through it.

If amplitude distortion is present, the diagonal line will flatten out at one or the other end, or both (Fig. 33-17a); in the case of an ellipse, one or both of the ends will be flattened by distortion (Fig. 33-17b).

The Lissajous test just described, can detect a much smaller amplitude distortion than the sine-wave test previously described is able to.

Frequency Response Tests of Audio Amplifier. The frequency response of an audio amplifier may be checked by applying sine-wave signals varying over the audio bandpass of the amplifier to the input of the amplifier and comparing the amplitudes of these signals at the amplifier input and output. The response may also be tested by applying square-wave signals of several frequencies to the input of the amplifier

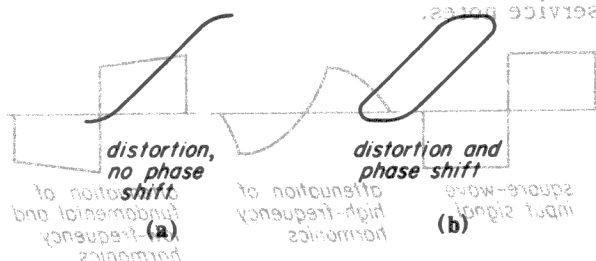


Fig. 33-17

and comparing the shape of these signals at the input and output of the amplifier.

Testing Frequency Response With Sine-Wave Signal. Earlier you learned that an oscilloscope can be used instead of a meter in many applications. For example, an oscilloscope can be used instead of a meter to measure the frequency response of an amplifier. The reason you might want to use an oscilloscope rather than a meter for this test is that the frequency response of an oscilloscope is better than that of an ordinary multimeter. Even though the response of the oscilloscope may not be absolutely the same at all frequencies in the audio pass band, the variation in response will not be enough to affect the test.

In order to make this test, frequencies from 50 cps to 12,000 cps are fed from an audio signal generator to an audio amplifier. At each frequency, the output from the amplifier is fed to and measured on the oscilloscope, which has been calibrated to read the amplitude of the voltages applied to it, as described earlier in this booklet. If the amplifier responds about equally to each of the frequencies fed to it, the frequency response of the amplifier is satisfactory for the entire band it is expected to pass under normal conditions. If there is a marked fall-off in response at any frequency (this test is intended only to reveal a marked fall-off), you know that the amplifier is responding poorly to that frequency. The output level of the signal generator should be kept low to avoid overloading the amplifier.

Using the signal generator that servicemen usually have, you will have to set the signal generator to each of the frequencies you wish to measure. Furthermore, you will have to rely on the frequency response of the signal generator itself, which may not be the same at all frequencies. Therefore, before making this test, it is necessary to test the frequency response of the signal generator by applying output directly to the oscilloscope and measuring the amplitude of the voltage for each frequency. Then, when the signal generator output is applied to the amplifier, and the amplifier's response

is read on the oscilloscope, you will have to take into account the uneven response of the signal generator at the frequencies that you send through the amplifier. In many cases, the output of the generator will gradually fall off as the generator is tuned to higher frequencies. Note the percentage by which the output falls off — 10%, 20%, etc. at frequencies representing the limits of the audio amplifier's bandpass.

When you have familiarized yourself with the way the output of the signal generator changes with frequency, connect the generator to the input of the amplifier, and attach the oscilloscope across the amplifier output. Keep the output of the audio signal generator low and the oscilloscope gain and vertical attenuator controls high, to prevent overload in the amplifier. Vary the frequency of the audio signal generator. If the response falls off in the same way as it did when the generator was fed directly to the oscilloscope vertical input, the frequency response of the amplifier is normal. If the response extends over a narrower range of frequencies — is 30% down at 5 kc, for example, instead of at 12 kc — the frequency response of the amplifier is incorrect. (It is assumed that the response is known to extend to 12 kc normally.) The response of individual stages may be similarly checked, when the response of the audio amplifier as a whole has been found to be improper.

Frequency response tests should be made at the setting of the audio amplifier volume control at which symptoms are objectionable. If the symptom is a muffled sound at a low setting of the volume control, for instance, the frequency response tests should be made with the volume control setting low.

Tone controls should be set to provide normal (unattenuated) low high-frequency response.

Square-Wave Test of Audio Amplifier.

The square-wave test of audio amplifiers is simple, speedy, and accurate. An instrument known as a *square-wave generator* is used for this test, which will reveal the frequency response, amplitude response, and phase response of an amplifier. As a serviceman,

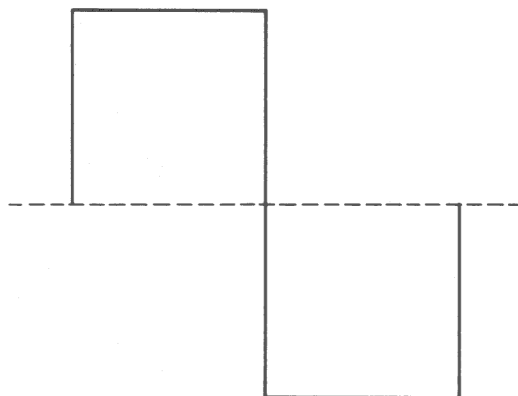


Fig. 33-18

you will be most interested in frequency response. The signal output of this type of generator, square in shape (Fig. 33-18) and known as a *square wave*, is applied to the input of the amplifier. The oscilloscope is connected first to the input and then to the output of the amplifier. The waveform seen at the output should be substantially the same in shape as that of the input signal if there is no trouble in the amplifier.

A square wave signal is made up of a fundamental signal and odd harmonics of the fundamental (third, fifth, seventh, etc.). In order that the original square-wave signal can be reproduced with reasonable fidelity at the output, harmonics, up to and including the twenty-first harmonic, must be passed by the amplifier without attenuation.

Figure 33-19 shows the effects of improper frequency response on a square-wave signal. You may see distortion similar to this when you make a square-wave test. In order to interpret your results, you must know whether the distortion is normal — that is, whether the design of the amplifier is responsible for the distortion or whether the distortion is due to a defect in the amplifier. You can get information about the amount of square-wave distortion that is normal for a particular amplifier from the manufacturer's service notes.

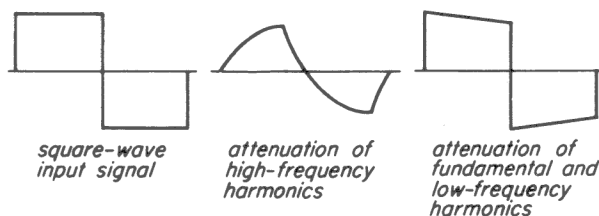


Fig. 33-19

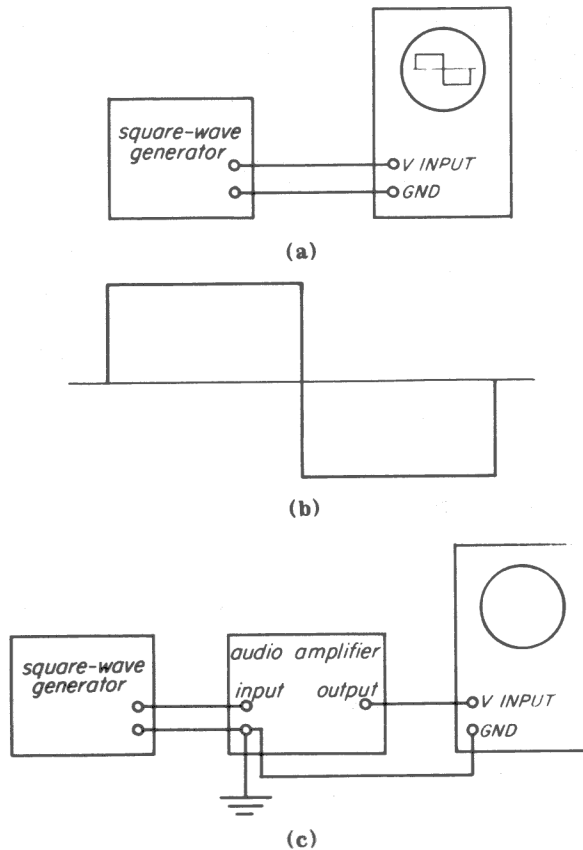


Fig. 33-20

In order to make a square-wave test of an audio amplifier, it is necessary to check the waveform of the signal put out by the square-wave generator. This can be done by connecting the square-wave generator output leads to the vertical input of the oscilloscope (Fig. 33-20a). The generator should be set at the low-frequency end of the amplifier bandpass. If this is 60 cps, for instance, the generator should be set to this frequency. The waveform seen on the oscilloscope, when the generator and oscilloscope vertical gain and/or attenuator controls have been properly adjusted, should resemble the waveform shown in Figure 33-20b. If the waveform observed is somewhat different either the response of the oscilloscope is not perfect at the applied frequency or the generator itself may not be developing a perfect square-wave output. Although such slight deviations in the shape of the signal are not important, seeing these deviations lets you know that the amplifier is not producing them.

After you have tested the square-wave generator, connect the equipment as shown in Fig. 33-20c. The square-wave generator

output control should be at a level low enough to avoid amplifier overload but high enough to provide an easily-inspected waveform image on the oscilloscope screen. If the amplifier has a tone control, set it to the position where neither low nor high frequencies are attenuated.

The amplifier can be tested at two frequencies. One test can be at the lowest frequency of the bandpass. Assume that this is 60 cps in the case we are considering. The second test frequency should be $1/20$ of the frequency at the upper limit of the bandpass, so that the 20th harmonic of this frequency falls at the upper limit of the bandpass. The 20th harmonic is easier to use in computations than the 21st, and is close enough to it so that error is negligible. Suppose the upper frequency limit is 20,000 cps. The upper test frequency should be 1,000 cps.

A square wave is made up of odd harmonics. If the fundamental is 60 cps, the odd harmonics are 180 cps (third harmonic), 300 cps (fifth harmonic), etc. Technically, the response of the amplifier is measured only at odd harmonics, not even ones. Couldn't the response be good at odd harmonic frequencies and not at even ones? Theoretically yes, but practically no. It is unlikely that the response will be good at 300 cps, for example, and poor at 360 cps. The square wave check is an adequate test of the amplifier over the range of frequencies that make up the bandpass of the latter because the frequencies sampled are representative of the entire range.

When an over-all amplifier check has shown that the frequency response of the amplifier is improper, individual stages can be similarly tested to localize the one in which the trouble is originating.

Checking Voltage Gain of Audio Amplifier Stages with Oscilloscope. When the volume of sound heard in a speaker fed by an audio amplifier is low, amplifier gain may be insufficient. An oscilloscope can be used to check the gain of individual amplifier stages.

Connect an audio signal generator (or the audio output of an r-f signal generator)

between grid and ground of the audio amplifier stage under test. Measure the signal voltage at the input with the oscilloscope. Adjust the generator output so that the input to the amplifier does not exceed the normal signal input to the stage. If you don't know how much this normal input is, keep the output from the generator low enough so that signs of overloading are not seen in the waveform reproduced on the oscilloscope screen when the oscilloscope is connected to the output of the stage.

When you have measured the input signal voltage, measure the output signal voltage. It may be necessary to recalibrate the oscilloscope, if the amplifier has high gain and no vertical attenuator is used in the oscilloscope. The ratio of the output voltage to the input voltage is the gain of the stage. If the output signal voltage is, for instance, 40 volts and the input voltage is 1 volt, the gain of the stage is 40:1 or 40.

When the gain has been measured, it is compared to the gain that is normal for the stage. Gain figures for different tubes are listed in the *RCA Receiving Tube Manual*, as well as in other tube manuals.

Tests in Phase Inverter and Push-Pull Stages. In order to check the operation of phase inverter and push-pull stages, feed an audio signal of 400 cps to the input of the phase inverter. Calibrate the oscilloscope; then connect the vertical input successively to the grids and plates of the push-pull output stages. The signal voltages at the inputs of the push-pull stages should be equal in amplitude; they should also be equal at the outputs of the push-pull stages.

Signal-Tracing Inoperative Audio Amplifier. An audio signal generator (or an r-f signal generator that provides an audio signal at front-panel terminals) may be used in conjunction with an oscilloscope to signal-trace an inoperative audio amplifier. To make such test, either of the following two procedures may be used:

1. Connect the source of audio signal to the input of the audio amplifier. Probe the grids and plates of the tubes in the various

stages of the amplifier with the vertical input lead of the oscilloscope, starting with the *first* stage. When you reach a circuit point at which the signal disappears (whereas it was visible at the circuit point just *preceding* this one), look for trouble between the two points. Suppose a signal is seen when the plate of the 3rd amplifier stage in a 4-stage amplifier is connected to the oscilloscope, but no signal is visible when the grid of the 4th stage is oscilloscope-checked. Trouble should be looked for between the output of the 3rd stage and the input to the 4th.

2. Connect the oscilloscope across the voice coil. Connect the signal source first to the plate, then to the grid, of the power amplifier; move successively *backwards* toward the grid of the input stage. Look for the first circuit point at which connection of the audio signal source produces little or no waveform on the screen. The trouble lies between this point and the one that just *follows* it. Suppose a signal is seen when the grid of the 2nd amplifier stage is oscilloscope-checked, but is absent with the oscilloscope connected to the plate of the 1st amplifier. Trouble should be looked for between these two points.

33-5. OSCILLOSCOPE TESTS FOR AM RECEIVERS

Overloading in the I-F Section of Broadcast AM Sets. When distortion is heard in a broadcast receiver, and the trouble is difficult to localize, make an oscilloscope check for overloading in the i-f amplifier section. To perform the test, feed a 30%-modulated r-f signal to the antenna input of the set. The receiver tuning dial should be at an off-station setting; the signal generator should be tuned to the same frequency as the receiver. The output of the generator should be advanced from the point where the AVC voltage is the same as when a typical station is being received. (Measure the AVC voltage in a similar receiver, with a normal-strength station coming in, to determine what the AVC voltage should be.)

Connect an r-f demodulator probe (a probe with a detector built into it) to the

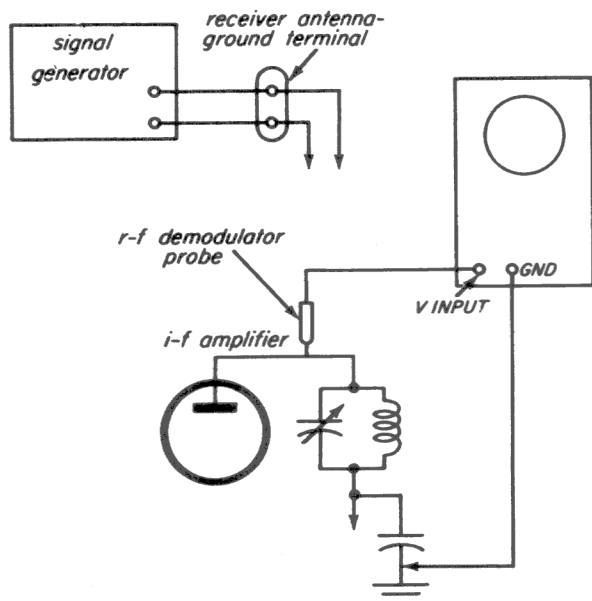


Fig. 33-21

vertical input of the oscilloscope. Apply the probe to the plate of the i-f stage. The setup is shown in Fig. 33-21. The normal waveform at this point is illustrated in Fig. 32-22a. If the waveform shown in Fig. 33-22b is seen, the i-f stage is probably overloaded. The likeliest cause of such overloading is insufficient AVC bias due to a component defect in the AVC circuit.

Improper Filtering of the I-F Signal in Broadcast AM Set. When the modulated i-f signal is improperly filtered, as a rule no symptoms will be heard in the radio receiver. But there may be coupling between audio and i-f leads; if i-f signals reach the audio section, they may be coupled back into the i-f stages, possibly causing regeneration or oscillation. A whistle is the likeliest result of such a condition.

To check whether i-f signals are mixing with the audio signal, feed a modulated i-f signal between grid and ground of the converter and connect the oscilloscope across the volume control (see Fig. 33-23). If the

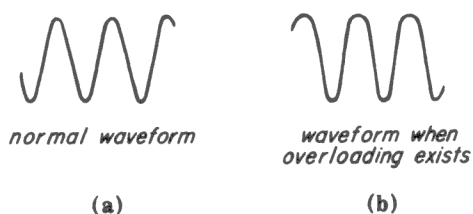


Fig. 33-22

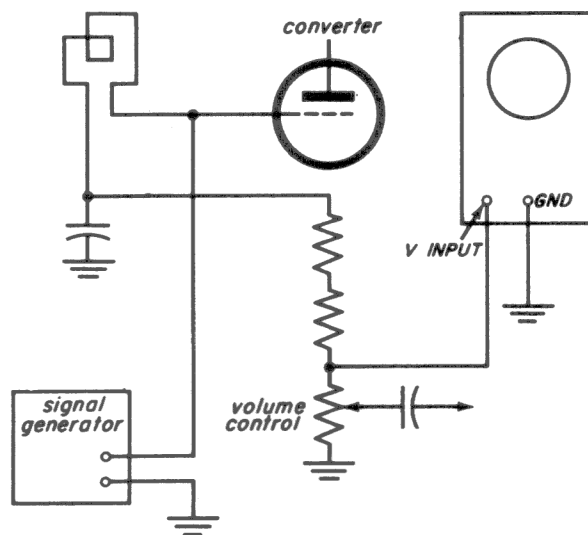


Fig. 33-23

i-f filtering is proper, the waveform of the signal developed across the volume control will resemble the one shown in Fig. 33-24a. If the filtering is improper, the waveform will be considerably thicker (Fig. 33-24b); the fuzziness is due to the intermediate-frequency signals that are riding along the audio waveform at a repetition rate too fast to permit them to be individually visible.

Testing the AVC Circuit. Troubles in the AVC circuit can produce distortion and/or low volume, as well as other symptoms. Rapid localization of such troubles is made possible when an oscilloscope is used.

To check the AVC action, loosely couple an r-f signal generator that provides an audio signal known to have a good sine-wave shape to the antenna input of the receiver. Do this by placing the generator leads near the loop or loop-stick commonly used in this circuit. Connect the vertical input leads of the oscilloscope across the 2nd detector load resistor (this is generally the volume control). Tune receiver to an off-station setting. Set the r-f generator dial to the same setting. The generator modulation should be on, and the modulation control advanced to 30 percent. Keep the r-f generator output



Fig. 33-24

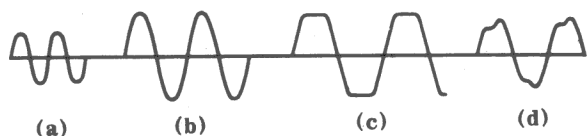


Fig. 33-25

just high enough to produce a visible waveform on the screen. The waveform should be a sine wave. (Fig. 33-25a).

Advance the r-f generator slowly. The waveform on the oscilloscope screen should get larger (Fig. 33-25b) until the point where the AVC takes hold, after which the output will rise very little or not at all as the input signal level is increased. The shape of the waveform should not become distorted (Fig. 33-25c,d) when the generator output is increased. If it is, there is trouble in the AVC circuit (a loss of capacitance or leakage in the AVC capacitor are probable in this circuit).

Localizing Hum. Hum may originate in three basic sections: power supply, audio section, and r-f/i-f section.

When hum is audible with the volume control turned to minimum, the power supply or the audio section is the source of the hum. To check the power supply, connect the oscilloscope across the output filter capacitor and measure the 60- or 120-cps ripple voltage. Its peak-to-peak value should not exceed 1/2 volt approximately. Smaller levels of ripple may produce objectionable hum in some a-c sets; larger ripple levels may be tolerable in many a-c/d-c receivers. The oscilloscope test just described therefore has a limited value. The advantage of the test is that if a large ripple is revealed, and excessive hum is audible, the source of hum is in all probability the power supply. If the ripple measured is small, supplementary component tests (bridging or replacing the filter capacitors, etc.) will be needed to definitely pin the blame on the power supply.

To check the audio stages, keep the volume control at minimum setting and probe the plates and grids of the audio tubes with the vertical input lead of the oscilloscope. The ground lead connects the chassis.

Start with the plate of the last tube, and work *backwards*. Find the circuit point (plate or grid) where hum is *not* produced when the oscilloscope is connected to it (and hum *is* seen when the oscilloscope is connected to the plate or grid immediately *following* this circuit point). When this point has been found, the stage where the hum originates has been localized.

If hum is heard only when a station is being received, check the r-f/i-f detector stages. Test for the presence of a hum signal at the cathode of each tube, unless the cathode is grounded. (Cathode-heater leakage is one of the chief sources of hum originating in the r-f/i-f stages.) If a tube has a 60-cps hum signal at its cathode, replace the tube to determine whether it is the source of trouble.

33-6. OSCILLOSCOPE TESTS FOR FM RECEIVERS

Sweep Alignment of FM Receivers. An oscilloscope is used when the visual method of alignment is employed for aligning FM receivers with a sweep signal generator. This method is more accurate than the one that uses a signal generator and a vacuum-tube voltmeter. The general procedure described below is broadly applicable to many FM radios. For more specific and detailed instructions on aligning a particular set, consult the manufacturer's service notes for that set.

Alignment of I-F Stages in FM Set using Discriminator. To sweep-align the i-f section of an FM receiver using a discriminator type detector, proceed as follows:

Connect the vertical-input lead of the oscilloscope to the hot side of the limiter grid-leak resistor through an isolating resistor (Fig. 33-26). The resistor should be of insulated composition having a value between 25,000 and 250,000 ohms. Try a 25,000-ohm resistor first; if the waveform seen on the oscilloscope during the alignment is distorted, and cannot be corrected by tuning adjustments, substitute larger resistors for the isolating resistor until the distortion is eliminated. The resistor re-

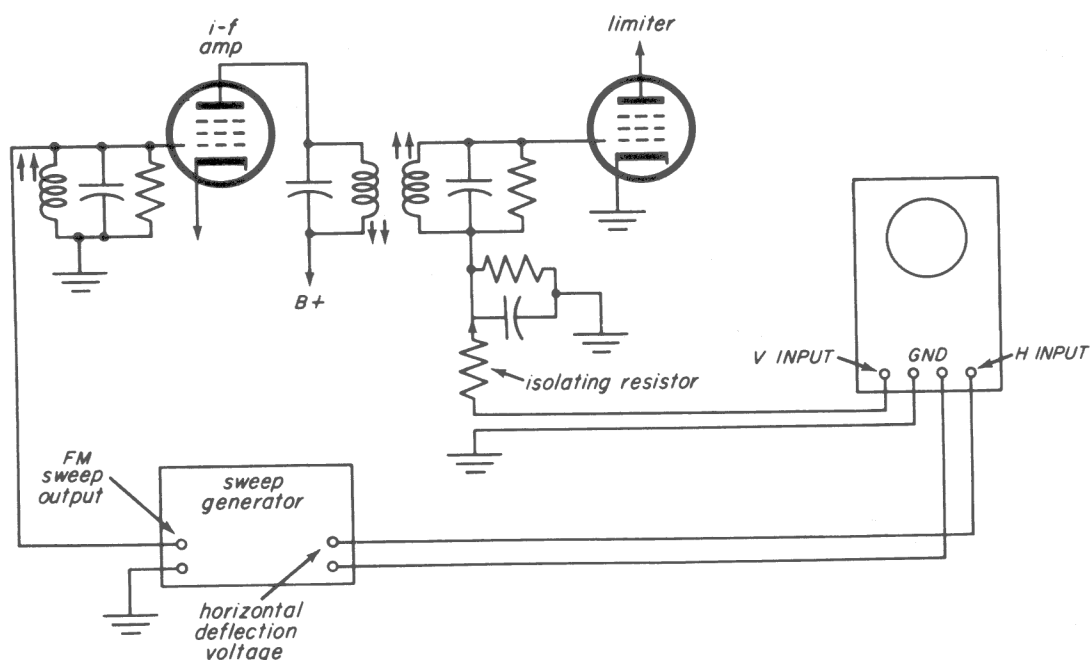


Fig. 33-26

duces the loading effect of the vertical input lead on the limiter grid circuit. The larger its value, the less the loading effect of the oscilloscope vertical input lead, but the lower is the sensitivity of the oscilloscope.

Connect the FM sweep generator between grid and ground of the i-f stage directly preceding the limiter. Set up the oscilloscope for external sweep. Connect the horizontal sweep output of the sweep generator to the horizontal input terminal of the oscilloscope, as shown in Fig. 33-26. The sweep width control is set to make the sweep width approximately 200 to 600 kc.

It is generally desirable to remove the r-f oscillator tube to prevent undesirable interaction between the oscillator signal and the FM generator sweep signal output. If the oscillator tube must be left in because the set uses a series-heater circuit, check whether it is producing interference by rotating the tuning dial of the FM receiver, while watching the response curve seen on the oscilloscope. If the response curve becomes distorted at some setting of the receiver tuning dial, or one or more unwanted *pips* are seen on the response curve (Fig. 33-27), the oscillator is probably producing interference. Leave the tuning dial of the

receiver at a point where such conditions do not occur in order to prevent the oscillator from interfering with the i-f alignment. If oscillator interference can't be eliminated in this way, short the oscillator tuned circuit to disable the stage.

With the sweep signal generator set to the center i. f. of the receiver, and the oscilloscope controls properly adjusted, a pattern similar to the one shown in Fig. 33-27 (without the pip) will be seen, provided the tuned circuit under test is not misaligned. If a double response is visible on the screen, adjust the phasing control on the sweep generator to the point where the two traces coincide. Set the output control of the sweep generator so that the waveform observed on the oscilloscope screen is as small as is compatible with proper viewing of the image. This precaution is taken to avoid overloading the receiver i-f stage. The vertical gain and attenuator controls on the oscilloscope

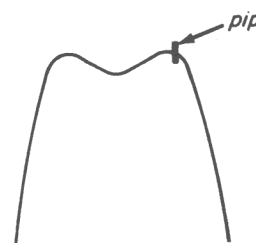


Fig. 33-27

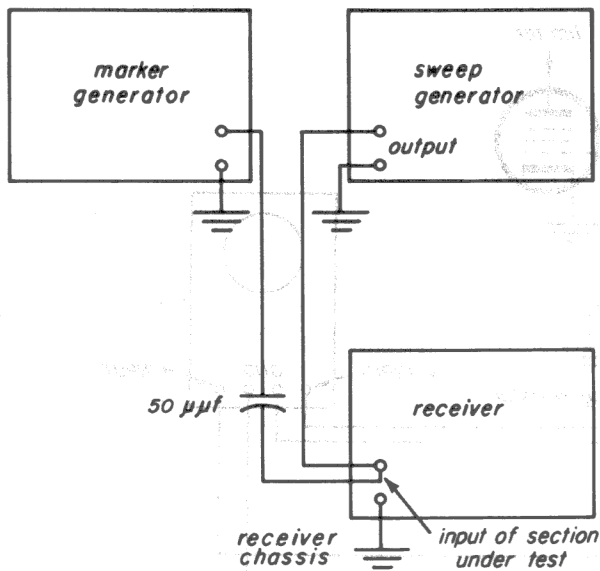


Fig. 33-28

should be set to provide maximum or near maximum sensitivity so that the sweep signal generator output will be as small as possible.

Some means of identifying the frequency limits of the response curve is needed. Marker signals serve this purpose. Marker signals may be provided by the sweep generator itself, as is often the case in sweep generators intended for the alignment of FM radios. Marker signals are also provided by separate signal generators; the signal generators are called *marker generators* when used in this way.

The signal produced by the heterodyning of the marker source and the FM sweep signal appears as a pip on the response curve (Fig. 33-27). At the point where the pip is seen, the response curve is at the frequency to which the marker generator is tuned.

The marker signal produced by the sweep generator is, in many cases, a fixed-frequency marker — that is, the frequency of the marker cannot be varied. If the sweep generator provides three marker signals — one to indicate the middle, the other two to indicate the ends of the response curve, no external source of marker signals will be needed. If only one marker signal is provided by the sweep generator — commonly 10.7 mc, the center i. f. — connection of a marker generator becomes desirable, to indicate the frequency limits of the response curve.

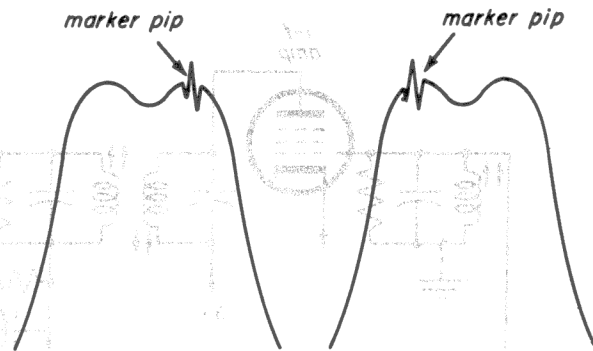


Fig. 33-29

The marker generator may be connected in parallel with the sweep generator output, with a small capacitor of approximately 50 μf inserted in series with the hot marker generator lead, to reduce the loading effect of the marker generator on the sweep generator (Fig. 33-28).

Tuning the marker generator through the i-f bandpass of the FM receiver will cause the pip or marker signal it puts out to move across the response curve. When the pip is at one edge of the response, see what the setting of the marker generator dial is; also check the generator dial setting when appropriate adjustment of the dial has brought the pip to the other side of the response curve (Fig. 33-29).

The amplitude of the marker generator output should be high enough to produce visible marker signals, but not so high that the response curve obtained on the oscilloscope screen is distorted.

The tuned circuits of the transformer feeding the limiter should be adjusted to provide a response of at least 200 kc (Fig. 33-30). With an intermediate frequency of 10.7 mc, the frequency setting of the marker

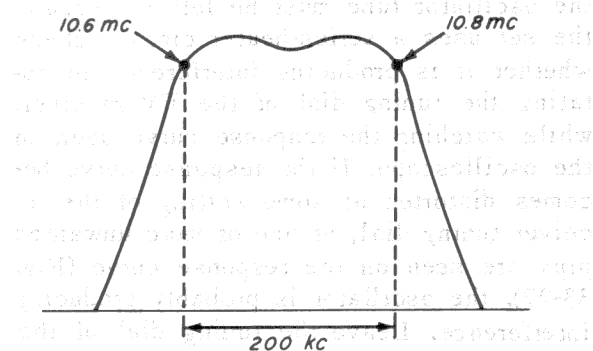


Fig. 33-30

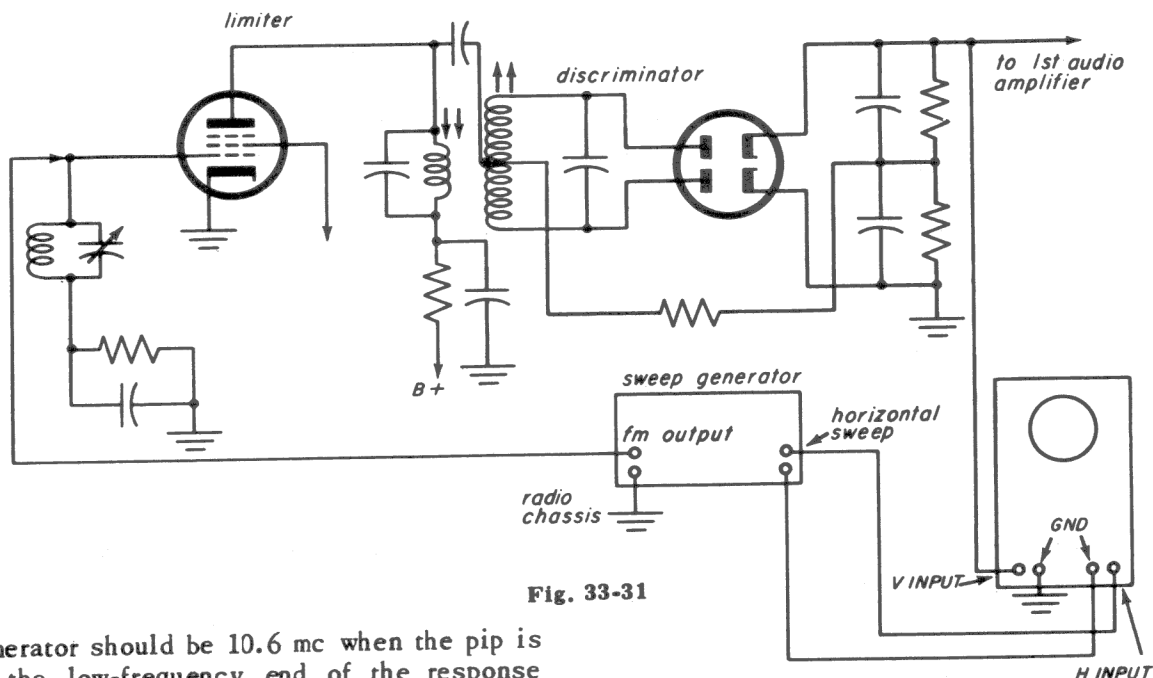


Fig. 33-31

generator should be 10.6 mc when the pip is at the low-frequency end of the response curve; the frequency setting of the marker generator should be 10.8 mc when the pip is at the high-frequency end of the response curve. The design of some receivers calls for a wider bandpass.

The setting of the tuning adjustments should be such that proper bandpass and maximum response curve amplitude are both provided; that is, the highest amplitude response compatible with adequate bandpass should be obtained.

When the i-f stage preceding the limiter has been aligned, connect the sweep generator between grid and ground of the preceding i-f stage, appropriately reconnecting the marker generator if one is used. Reset the tuning adjustments of this stage until the response curve is correct (bandpass is adequate and amplitude of response is maximum). The sweep (and marker) generator output should be reduced, to prevent overloading of receiver stages. Work backwards in this way until all the i-f stages in the receiver have been aligned. To align the 1st i-f stage, connect the sweep generator between grid and ground of the mixer.

Aligning the Discriminator. Most FM receivers use either a discriminator or a ratio detector to demodulate the FM signal. The detector is commonly aligned after the i-f stages. To align a discriminator stage, pro-

ceed as follows:

Connect the sweep generator between grid and ground of the 1st i-f tube. Set it to the center i.f. Connect the external marker generator (if one is needed) in the same way as previously described, but keep its attenuator control at zero setting for the time being. Attach the oscilloscope to the discriminator output as indicated in Fig. 33-31. Feed the sweep signal generator sine-wave deflection signal to the horizontal input terminals of the oscilloscope, and switch off the time-base generator of the oscilloscope. Adjust the sweep signal generator output to provide a small but easily inspected response curve on the oscilloscope screen. The response seen on the oscilloscope should resemble the one shown in Fig. 33-32 (unless the discriminator tuned circuit is

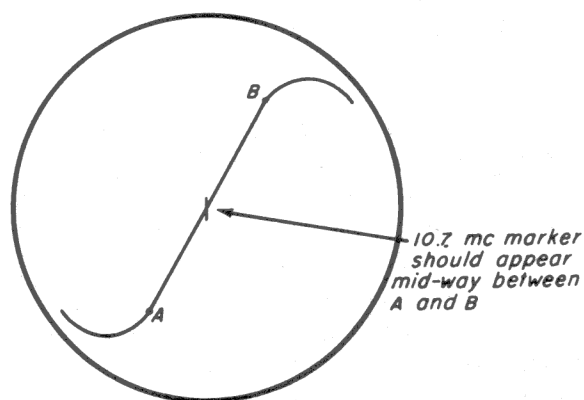


Fig. 33-32

vide a response curve similar in shape to the one illustrated in Fig. 33-29. The curve should have maximum amplitude and adequate bandpass. Next, tune the receiver and sweep generator to 105 mc, and reset the appropriate r-f and oscillator tuning adjustments for maximum response and adequate bandpass at this frequency setting. The sweep-width control of the sweep generator should be advanced sufficiently to permit the entire response curve to be seen on the oscilloscope during this test.

To align the oscillator and r-f stages in a receiver using a ratio detector, keep the oscilloscope in the position recommended for alignment of the ratio detector and adjust the appropriate tuned circuits for maximum amplitude, optimum linearity and proper bandwidth of the S curve, with the sweep generator and receiver successively tuned to 90 and 105 mc.

33-7. DETERMINING FREQUENCY OF AN UNKNOWN SIGNAL

At some time during your radio service work, you may be called upon to determine the frequency of a signal. For instance, you may have to check the frequency calibration of a beat-frequency type audio signal generator. You can find out what the frequency of a signal is through the use of Lissajous figures, gear-wheel patterns, or grid modulation. These methods are applicable only when the unknown frequency falls within the bandpass of the oscilloscope's vertical and horizontal amplifiers.

Lissajous Patterns. A Lissajous figure is the pattern that results when the variation of one sine wave is plotted along the vertical axis of a graph and the variation of another sine wave is plotted along the horizontal axis of the same graph. Lissajous figures can be produced on the screen of an oscilloscope by applying one sine-wave voltage to the vertical deflection plates of an oscilloscope and another sine-wave voltage to the horizontal deflection plates.

Figure 33-34 shows what happens when a sine wave is applied to the horizontal de-

flection plates of an oscilloscope and another sine wave of twice the frequency is applied to the vertical deflection plates. The sine wave applied to the horizontal plates is the sweep voltage and is shown at the bottom of the figure. On the right hand side of *a* of the figure, the sine wave applied to the vertical plates is shown. Notice that it has twice the frequency of the sine wave applied to the horizontal plates. The sine wave applied to the vertical plates is divided into twenty-four equal time intervals. At the bottom of Fig. 33-34, the sine wave applied to the horizontal plates is also divided into twenty-four equal time intervals. Vertical lines run upward from each of the numbers indicating a time interval on the sine wave applied to the horizontal plates. Horizontal lines run across from the sine wave in Fig. 33-34*a* to the left of the figure. The gridiron formed by the intersection of the lines from the two sine waves represents the screen of an oscilloscope.

Let's follow the way in which the figure-eight pattern shown on the screen in Fig. 33-34*a* is formed. The line from point 1 of the sweep voltage intersects the line from point 1 of the vertical voltage right at the center of the figure eight.

As the sweep voltage starts to rise, the vertical voltage starts to rise too, and we plot the intersections of points 2, 3 and 4. By point 5, the first cycle of vertical voltage has already begun to go down from its peak. On the other hand, horizontal voltage is still rising, so the sweep on the oscilloscope is still moving toward the right. As a result, the curve represented on the screen goes down and to the right. It is only after point 7 that the sweep voltage falls from its peak and the trace begins to move back to the left. If you follow through the entire cycle of sweep voltage (two cycles of vertical voltage), you can see that the pattern produced by connecting the twenty-four points of intersection produces the figure-eight pattern shown in Fig. 33-34*a*.

The pattern shown in Fig. 33-34*a* results when both sine waves are in phase; that is, both waves start rising from zero at the same time. In *b*, *c*, and *d*, you can see what hap-

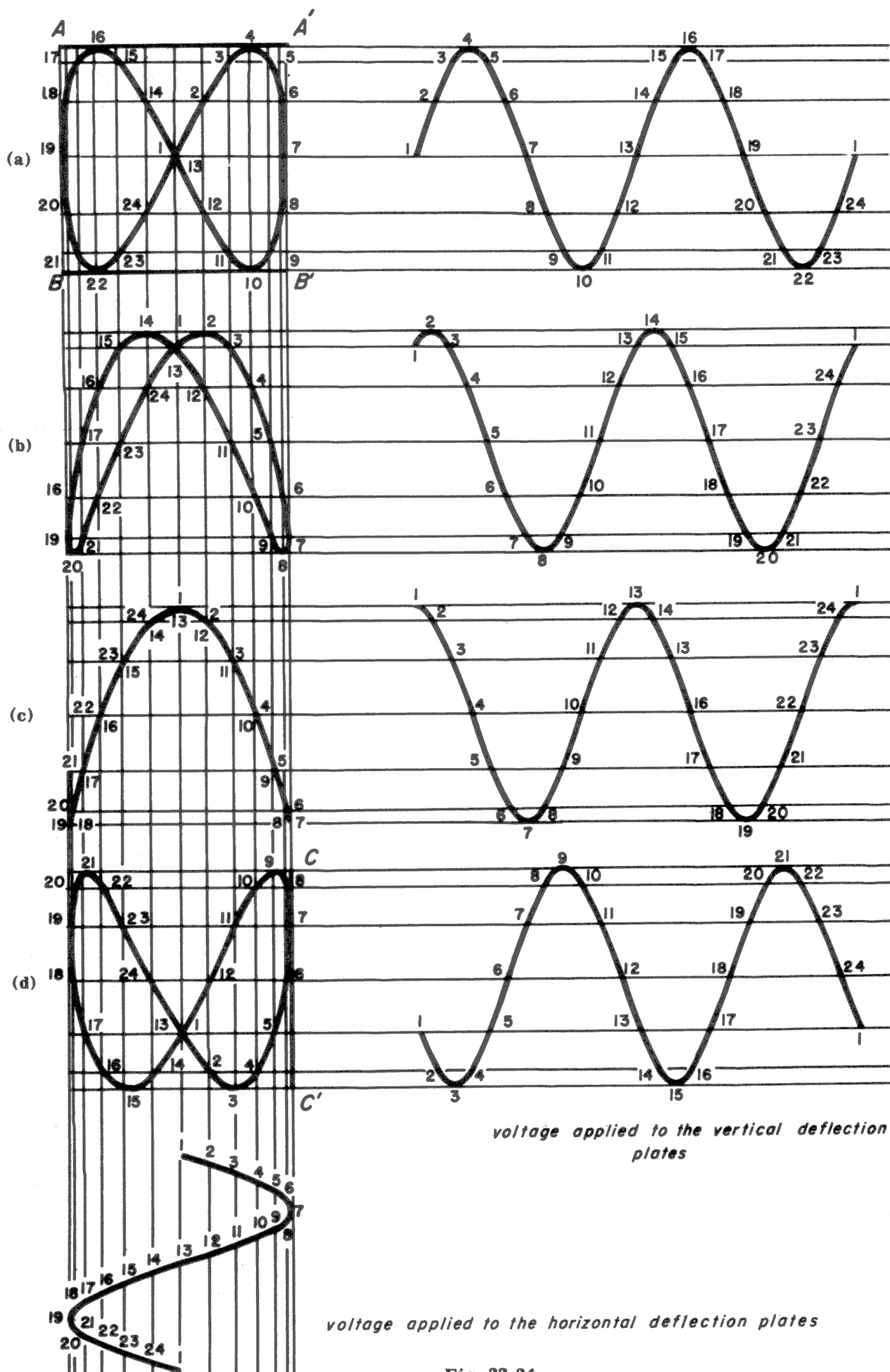


Fig. 33-34

pens when the two waves are not in phase.

The ratio of sweep frequency to vertical frequency in Fig. 33-34 is 1:2. Other ratios would produce other patterns on the screen. However, no matter what pattern a ratio of vertical sine-wave voltage to horizontal sine-wave voltage produces, you can always tell what that ratio is. Furthermore, if you know what the frequency of the horizontal voltage is, knowing the ratio will enable you to calculate the frequency of the vertical voltage. You can see this point with the aid of Fig. 33-34a. Notice the lines connecting points A and A' at the top of the figure and points B and B' at the bottom of the figure. The waveform touches each of these lines twice. On the other hand, if you drew a line beside the figure, as is done between points C and C' in Fig. 33-34d, you could see that the waveform contacts this line only once. The one time that the waveform touches line C-C' and the two times that the waveform touches either line A-A' or B-B' can be expressed as a ratio of 1:2. This is the ratio of the sweep frequency to the vertical frequency. You can apply this test to any one of the waveforms shown in Fig. 33-34, even to Fig. 33-34c, although in that figure only line B-B' is usable with line C-C'.

This process of comparing the number of times the waveform figure touches a vertical line like line C-C' with the number of times the waveform figure touches a horizontal line is expressed as follows in a formula:

$$\frac{\text{Number of points at which the figure is tangent to a vertical line}}{\text{Number of points at which the figure is tangent to a horizontal line}} = \frac{\text{Frequency (deflection) applied to horizontal plates}}{\text{Frequency applied to vertical plates}}$$

When you have a ratio set up like this and you know the terms of one side of the ratio, you simply substitute the same terms into the other side of the ratio. For example, when you inspect Fig. 33-34, you can see that the ratio is 1:2.

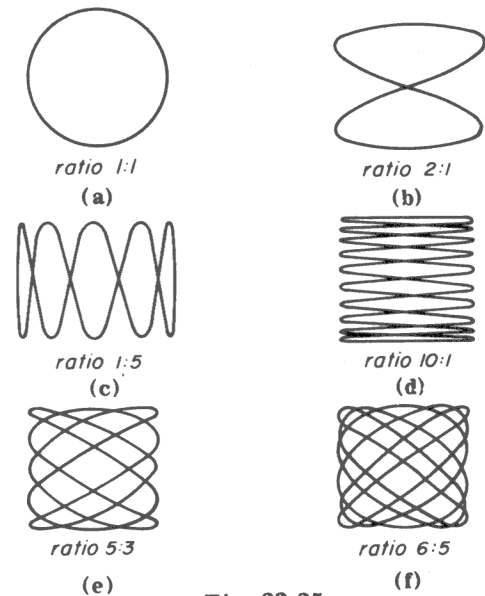


Fig. 33-35

Try using the same system with the waveforms shown in Fig. 33-35 and compare your results with the ratios given in the figure.

You have seen that it is possible to determine the ratio of the sweep frequency to the vertical frequency by examining the pattern of the screen. Once you know the ratio, if you know the frequency of the sweep voltage you can calculate the frequency of the vertical voltage. We can set up a formula for making these calculations as follows:

$$\text{Frequency of vertical voltage} = \frac{\text{horizontal frequency} \times \text{ratio of horizontal frequency to vertical frequency}}$$

Let's consider the case of the signals in Fig. 33-34. The ratio of sweep frequency to vertical frequency is 1:2. If the sweep frequency is 60 cycles, the vertical frequency is twice as much, or 120 cycles. Let's take the example of Fig. 33-35f. There, if the sweep frequency is 60 cycles, the vertical frequency is 50 cycles.

Frequency Determination by Gear-Wheel Pattern. When the ratio between the known and unknown frequencies is high, the Lissajous figure method of frequency identification introduces difficulties, since the numerous points of the pattern are difficult to count accurately. Use of a gear-wheel pattern is preferable in such cases. The pattern is produced by connecting an audio signal

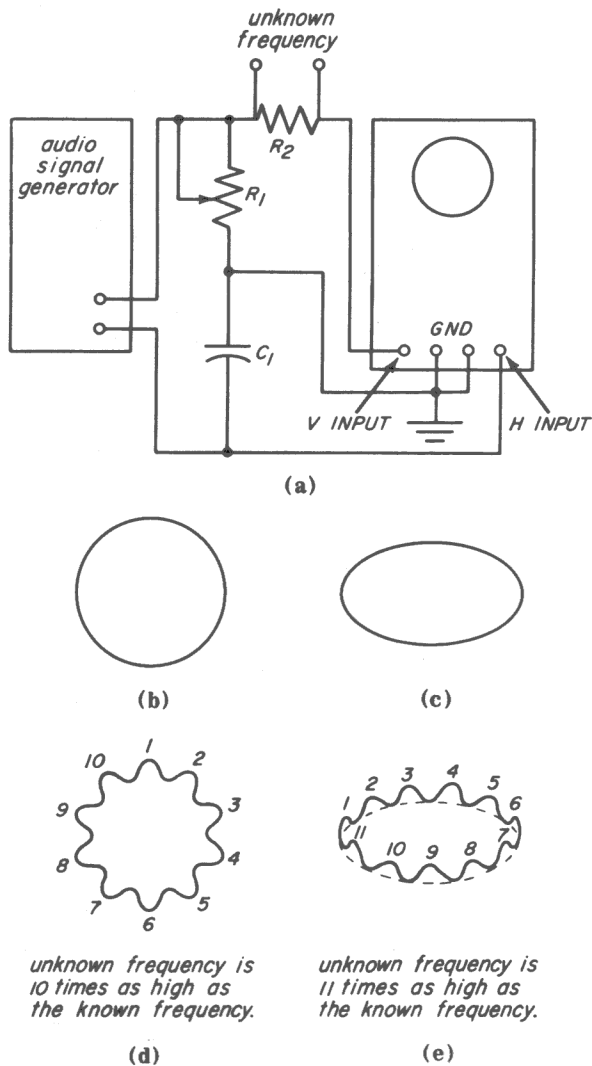


Fig. 33-36

generator, oscilloscope, and source of unknown signal in the manner illustrated in Fig. 33-36a. The circuit shown is for a balanced signal generator. In actual practice, you will have to modify the circuit if your signal generator is unbalanced or there is excessive hum pickup at the oscilloscope. The time-base generator of the oscilloscope is switched off for this test.

The output of the audio signal generator is applied to both sets of deflecting plates. Because of C_1 and R_1 , the voltage applied to the vertical plates is 90 degrees out of phase with the voltage applied to the horizontal plates. As a result, an elliptical pattern appears on the screen of the oscilloscope. (When the capacitive reactance of C_1 is equal to the resistance of R_1 , the pattern on the screen is a circle. A circle can be ob-

tained when the capacitive reactance is not equal to the resistance by adjusting the horizontal and vertical gain controls of the oscilloscope.)

The ellipse or circle on the screen of the oscilloscope is produced by a known frequency from the audio signal generator. When an unknown frequency is applied across R_2 , the unknown frequency is mixed with the known frequency on both sets of deflection plates. As a result, the circle (Fig. 33-36b) or ellipse (c) becomes a gear-tooth pattern (such as d and e). The number of teeth in the gear pattern equals the number of times the unknown frequency is greater than the known frequency. For example, if the known frequency that produces the circle in b is 600 cps, the ten teeth produced in that circle, as shown in d, indicate that the unknown frequency is 6,000 cps. In order to use this method of measuring an unknown frequency, it is necessary to have a known frequency much lower than the unknown frequency.

Frequency Determination by Grid Modulation. This method can be used only with an oscilloscope that has an intensity modulation input, because the method depends upon being able to apply the unknown signal either to the cathode or the grid of the oscilloscope. By means of varying the cathode or grid potential, the pattern on the screen can be partially blanked out to form a pattern. The audio signal generator and oscilloscope are connected as shown in Fig. 33-37. C_1 and R_1 are used, as in the method previously described to produce an

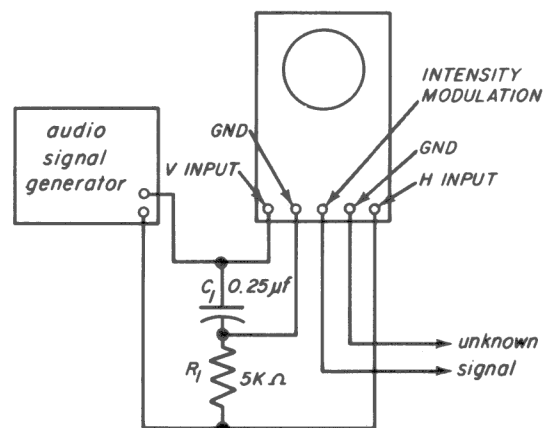


Fig. 33-37

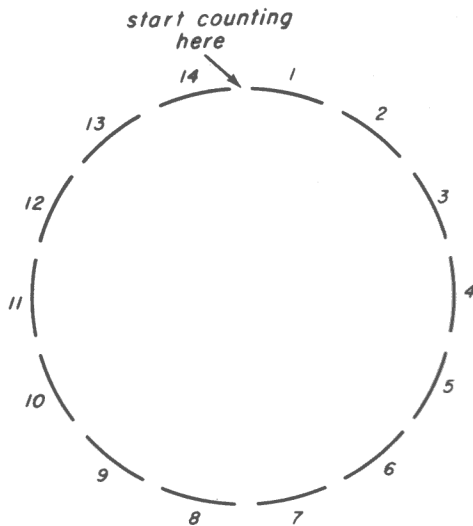


Fig. 33-38

elliptical or circular pattern.

The circle or ellipse seen on the screen with the unknown signal disconnected from the oscilloscope breaks up into dotted lines (Fig. 33-38) when the signal is connected to the INTENSITY MODULATION post. To determine the frequency of the signal, multiply the frequency setting of the audio signal generator by the number of dotted lines visible. Start at the top center of the pattern, to give yourself a fixed reference point in order to make counting easier. Use an audio signal generator setting that will produce a relatively small number of dotted lines.

The intensity setting of the oscilloscope should be minimum during this test to increase the contrast between the blanked out and the visible portions of the circle or ellipse. A higher setting will lighten the portions of the trace that should be dark.

Caution: To prevent damage to the oscilloscope, do not apply a voltage to the INTENSITY MODULATION jack that exceeds the limits specified by the oscilloscope manufacturer. For instance, the manufacturer may warn that the maximum positive peak of the signal applied at this point should not exceed 2 volts, with the intensity setting maximum, or 70 volts with the intensity setting minimum. Failure to observe this precaution may damage the oscilloscope CRT. (Although the exact frequency of the signal that is going to be applied to the INTENSITY MODULATION terminal is un-

known, its amplitude may readily be measured by using the method described in an earlier part of this booklet.)

33-8. MEASURING IMPEDANCE OF AUDIO-FREQUENCY COMPONENTS

When you replace an audio-frequency choke, coil or transformer you should know the impedance of the original unit. This data may not be available in the set manufacturer's service notes. The oscilloscope can be used to make such measurements. Let's use an oscilloscope to measure the impedance of the voice coil in a loudspeaker. If the voice coil is not open or short-circuited, its impedance may be readily measured with an oscilloscope.

Connect an audio signal generator, single-pole double-throw switch, potentiometer, and oscilloscope in the manner indicated in Fig. 33-39. For best results, the potentiometer should have a maximum resistance somewhat but not too much higher than that of the impedance to be measured. If you are going to measure the impedance of a voice coil, for instance, you know the reading will generally be less than 20 ohms; a potentiometer with a maximum resistance of 30 ohms or thereabouts would be most useful in such a case.

For greater accuracy, a suitable decade resistance box can be used in place of the potentiometer. Such units permits the switching in of various desired values of resistance.

The audio signal generator should be set to the frequency at which the impedance of the unit under test is generally measured. For voice coils, this frequency is commonly 400 cps. If you don't know what the test frequency normally is, make it either 400 or 1,000 cps.

Now set the spdt switch to position 2. The waveform reproduced on the oscilloscope screen represents the signal voltage developed across the unknown impedance. It is equal to the audio signal generator output signal minus the signal voltage used up across R_1 (Fig. 33-39c).

If the unknown impedance was equal in value to the resistance setting of the po-

tentiometer, half the signal generator voltage would be developed across R_1 , the other half would appear across Z_X , and the amplitude of the signal seen on the oscilloscope at this setting of the switch would be the same as when the switch was set to position 1. It probably won't be the same however. Measure the amplitude of the signal present on the screen with the switch at position 2. Then shift back to position 1, and adjust

the potentiometer to the point where the amplitude of the signal is the same as it was with the switch at position 2. Set the switch to position 2 again and recheck the signal amplitude at this setting. Work back and forth in this way, until the signal amplitude at both settings is identical. When it is, the impedance of the unit under test will be the same as the resistance setting of the potentiometer. All you have to do now is measure this resistance with an ohmmeter. The impedance of the unit is the same as the resistance measured between points A and B of the potentiometer. The replacement unit should, under the same test conditions, provide an identical reading.

33-9. OSCILLOSCOPE PROBES

Servicemen use four chief types of probes with oscilloscopes: shielded direct, resistive isolating, low-capacitance, and demodulator probes.

Shielded Direct Probe. The shielded direct probe is a shielded lead with a probe at the end of the lead. Using a probe permits connection of other probes to the oscilloscope quickly. A direct probe is used when the oscilloscope is to be connected to receiver circuits whose operation will not be seriously affected by the capacitance and inductance of the oscilloscope cable. Circuits of this kind have a relatively low impedance. The shielding of the probe is essential to prevent it from being affected by stray a-c voltages—particularly 60-cps line voltage.

Resistive Isolating Probe. This is a probe that has a built-in resistor. Many servicemen make the equivalent of such a probe by simply adding a resistor in series with the vertical input lead of the oscilloscope. A resistive isolating probe minimizes the shunting effect of the vertical input cable and the capacitance of the vertical input circuit of the oscilloscope. The sensitivity of the oscilloscope is reduced by the resistance in series with the probe. The reduction in sensitivity varies with the frequency of the applied signal (Fig. 33-40). Therefore, nonsinusoidal waveforms, which are made up

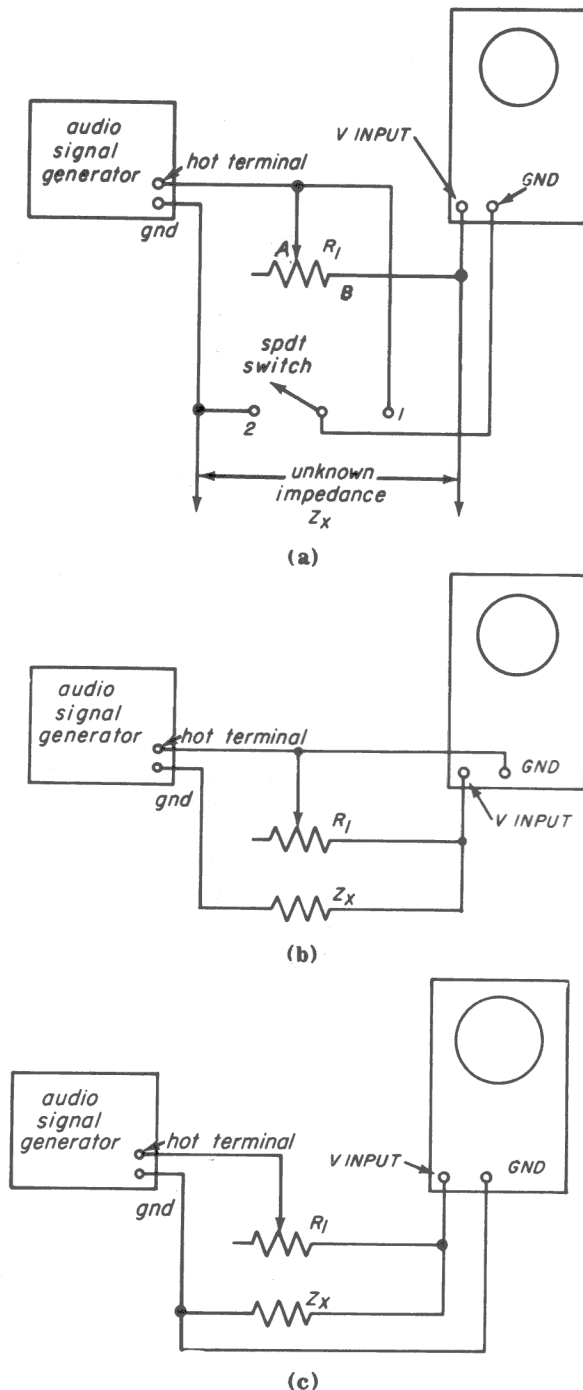


Fig. 33-39

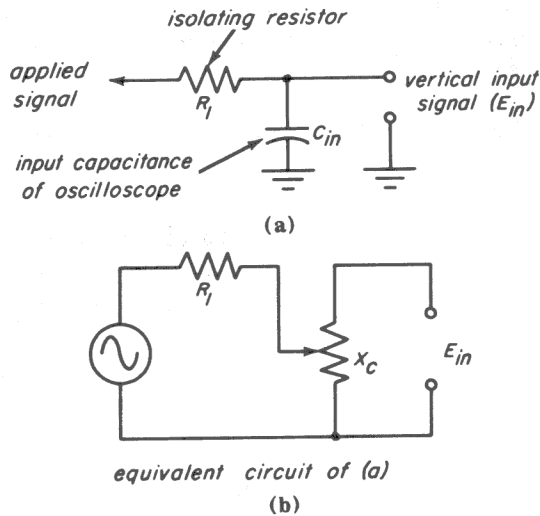


Fig. 33-40

of signals of many frequencies, may be distorted to some extent when they pass through a probe of this type to the vertical input of the oscilloscope.

Low-capacitance Probe. A low-capacitance probe (Fig. 33-41) is needed when the vertical input of the oscilloscope is to be connected to a high-impedance circuit, or a circuit point at which there is a waveform with high-frequency components, or to a tuned circuit. A probe of this kind increases the impedance presented by the oscilloscope vertical input to the circuit under test, just

like a resistive isolating probe does. The low-capacitance probe is frequency-compensated with the result that *all* frequencies in the bandpass of the oscilloscope vertical amplifier are *equally* attenuated in passing through the probe. No distortion of signals is therefore introduced by the probe.

The sensitivity of the oscilloscope is considerably reduced by the use of a low-capacitance probe. If the oscilloscope is not sensitive enough or the signal measured isn't large enough, the signal attenuation produced by the probe may result in the reproduction of a waveform on the screen that is too small to be useful.

When the vertical input of the oscilloscope is direct-coupled to the 1st vertical amplifier stage, and the probe is to be connected to a high-impedance circuit point at which a d-c voltage is present with respect to ground, a blocking capacitor of approximately $0.5\text{-}\mu\text{f}$ or higher should be used in series with the probe. The capacitor should be of high quality, and have a low leakage. The voltage rating of the capacitor should be greater than the d-c voltage between ground and the circuit point to which the capacitor will be connected.

The capacitor is inserted to prevent a d-c shunt path from being set up between the circuit point to be probed and ground in Fig. 33-42. The probe is connected to point X , and d-c current flows from ground through R_2 , R_1 , R_p , and R_3 . If such a shunt path is present, the d-c voltage between ground and the circuit point to be probed will be reduced, and the circuit operation will alter.

Oscilloscope manufacturers generally make probes specifically designed for use

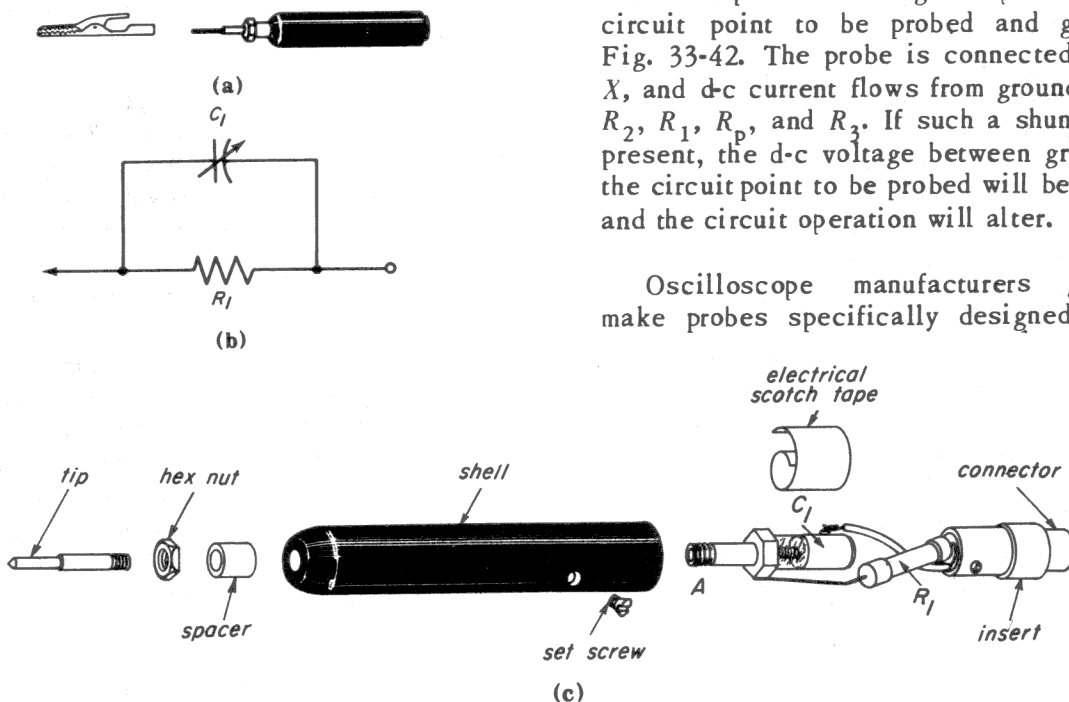


Fig. 33-41

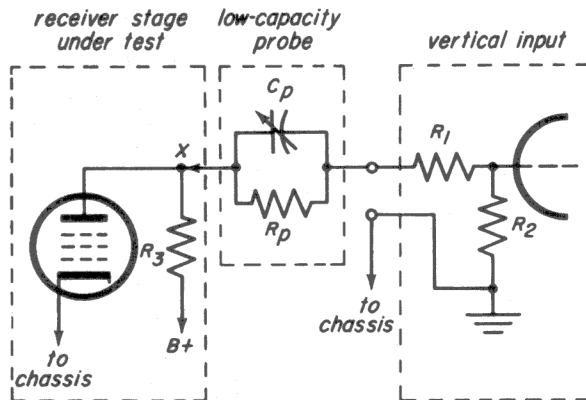


Fig. 33-42

on their instruments. If you are going to buy a low-capacitance probe, you should purchase it from the manufacturer of your oscilloscope in order to be sure that the probe will work properly with the oscilloscope.

The low-capacitance probe contains a variable capacitor. The capacitor should be adjusted in accordance with the manufacturer's instructions. If the capacitor is not properly adjusted, the frequency response of the oscilloscope may be impaired; its sensitivity will be altered as well.

Demodulator Probe. Sometimes, it is desirable to inspect the modulation waveform of a high-frequency carrier signal. When you are troubleshooting an i-f stage, you may want to check if signal is reaching the plate of the stage. You can't check for a signal waveform at the plate by connecting the vertical input lead to this point if the frequency of the carrier signal is beyond the bandpass of the vertical amplifier of the oscilloscope. The audio modulation of the carrier is low enough in frequency to be passed by the vertical amplifier and is therefore suitable for checking.

In order to inspect the modulating signals, it is necessary to remove the carrier. This is done with a demodulator probe. Demodulator probes often have a crystal detector that detects the carrier modulation in the same way as does the detector in an AM radio receiver. The demodulated signal is fed to the vertical input of the oscilloscope and reproduced on the screen.

The recovery of the modulation indicates the carrier is also present. Therefore, a test

of the kind just described serves as an effective check for the presence of signal in i-f circuits.

The demodulator probe is also known as an r-f probe or detector probe.

The response of an individual tuned i-f stage may be checked by passing a signal from a sweep generator through the stage and applying the demodulator probe to the output of the stage. The demodulator probe is also useful for signal tracing in i-f stages of radio receivers.

The oscilloscope used in conjunction the demodulator probe will have to have a very high sensitivity so that small amplitude r-f signals can be detected and reproduced on the screen. With inexpensive oscilloscopes of moderate sensitivity, it is likely that no r-f signal waveform will be seen if the plate of an r-f amplifier, or some similar circuit point where the signal level is very low is probed.

33-10. PRECAUTIONS TO OBSERVE IN USING OSCILLOSCOPE

Avoiding Injury. You can be injured by a CRT *implosion* which is the term used to describe a sudden cave-in of the glass surface of the tube. The layman would call this an *explosion*. After the tube has caved in, the particles into which it has broken are propelled into the air with great force. Implosions of 3-, 5-, and 7-inch C-R tubes (the sizes commonly used in oscilloscopes) are not liable to have fatal results, but flying glass may damage your eyes. Minimize the chances of an implosion by not scratching the surface of the tube. A scratch may weaken the glass to the point where it is unable to resist the heavy atmospheric pressure on it and an implosion will follow. The surface you will commonly have access to is the one that forms the viewing screen at the front of the oscilloscope. The chances are that you won't ordinarily have to touch this surface unless you are replacing a defective CRT or are rotating the tube from outside the front panel to straighten the screen.

If you handle the CRT, remove any rings you may be wearing so as to avoid scratch-

ing the tube.

When you have removed the CRT from its socket and must put it down somewhere, place it on a soft clean cloth – don't put it down on a hard or gritty surface.

Be careful not to bring tools too close to the CRT. You may accidentally bang a tool against the tube.

When you remove the case of the oscilloscope, there is danger of shock from the high voltage. Follow the precautions listed below:

1. Do not work alone. Another person should be present to remove power and apply resuscitation in case of accident.

2. Avoid close proximity to high-voltage points. If you are unfamiliar with the equipment, find out where the high-voltage points are located. Remember that high voltage may appear at unexpected points in defective equipment.

3. Power should be removed from high-voltage points, if possible, before the test leads are connected.

4. If it is impractical to turn power off, make sure that the ground clip of the test equipment is securely attached. Keep fingers far back from probe tip. Avoid contact between any part of the body and ground. Obtain dry insulating material to stand on, if floor is not insulated. Do not lean against equipment racks, metal bulkheads, or any object which can provide a ground.

5. Short-circuit all filter capacitors, if possible, before attaching test leads.

6. Never use leads with broken insulation.

7. Always disconnect test leads immediately after measurement is completed.

8. Do not connect ground lead of the oscilloscope to a high-voltage point! The ground lead of the instrument is connected internally to the case.

In many oscilloscopes, the deflection plates are connected to terminals at the

back of the oscilloscope. In some cases, the deflection plates are at *B* potentials with respect to the oscilloscope case. Shifting the position of the oscilloscope while it is on or picking it up, may bring your hand in contact with a hot terminal and subject you to shock. Check your oscilloscope instruction manual and/or schematic to determine if any rear panel terminals are hot. If your oscilloscope has such live rear terminals on it, don't move it about or handle the rear terminal board while power is being applied.

Avoiding Damage to Oscilloscope. At certain times during the adjustment of the oscilloscope controls, an undeflected scanning spot will appear on the screen. When you see such a spot, keep the setting of intensity control minimum. A very bright scanning spot – particularly a very bright, *sharply-focused* spot – represents a heavy and continuous electron bombardment of one small point on the screen. The screen coating may be burned away at this point if the bright scanning spot is permitted to remain stationary for a considerable length of time. Bring in a waveform image, or at least a horizontal line, as quickly as possible by suitable adjustment of the oscilloscope controls.

To avoid damaging the capacitor in the oscilloscope input circuit, do not apply a-c voltages to the vertical input in excess of the permissible input voltage specified by the manufacturer. In many cases, this maximum is 600 volts.

Cautions on Using Leads. A shielded vertical input lead is necessary to avoid pickup of undesired signals (chiefly 60-cps signal radiated from power-line wiring). The more sensitive the oscilloscope is, and the higher its input impedance, the greater this signal pickup tends to be in the absence of a properly-shielded input lead. The undesired signal picked up, as well as the desired signal, will produce vertical deflection in the oscilloscope; therefore, the waveshape reproduced on the screen of the CRT will be distorted.

If a shielded vertical input lead is temporarily unavailable, and unshielded leads

are used, keep the leads from oscilloscope to receiver as short as possible. The shorter the leads, the smaller is the voltage that can be induced in them by stray fields.

To avoid receiver oscillation and other causes of improper waveforms, connect the ground terminals of the oscilloscope, and all equipment used in conjunction with it, to a common ground point on the receiver chassis—that is, to a single small area on the chassis. While this precaution is not always necessary, it does minimize the possibility of undesired effects that could result in an improper waveform image on the screen. It is preferable to use metallic-shield braid or large-diameter wire for making grounds between test equipment and receiver chassis.

Distortion Introduced by Oscilloscope.

Distortion of the waveform seen on the oscilloscope may be caused by the oscilloscope itself rather than by a fault in the receiver. Overloading of the oscilloscope input stage will take place if the signal voltage applied to it is excessive. Overloading is liable to occur in an oscilloscope with a vertical attenuator switch if the attenuator switch is placed at too high a setting (i.e., a setting at which vertical amplifier sensitivity is too high) and the gain control is used to reduce the waveform to dimensions best suited for viewing. To avoid such trouble, keep the vertical attenuator switch set to provide as low a sensitivity as possible. Advance the vertical gain control to maximum, if necessary, to make the size of the waveform adequate. (The vertical gain control is generally located at some point following the 1st vertical stage when a vertical attenuator switch is used; advancing it to maximum will not overload the first stage. The vertical attenuator switch, on the other hand, is at the input of the first stage; an improper setting of the switch may produce overload.)

When the waveform seen on the screen should be a sine wave, but is not—i.e., the waveform is distorted—try inserting a carbon resistor of 25,000 to 250,000 ohms in series

with the vertical input. If the waveform shape becomes normal, the input circuit of the oscilloscope is loading down the receiver circuit. The resistor may be left in series with the vertical input lead to prevent the loading effect, or a low-capacitance probe may be used as the vertical input lead. A low-capacitance probe will have to be used when the waveform to be inspected normally has a nonsinusoidal shape, and the loading effect of the oscilloscope causes the waveform to be distorted.

The waveform may be distorted if the oscilloscope is positioned near a power transformer or other source of a strong magnetic field. Distortion produced by an external magnetic field twists the waveform out of shape in an irregular fashion; the effects are completely unlike those produced by other troubles. To test for as well as remedy such distortion, move the oscilloscope a distance from the suspected source of the disturbance or move it into a position where pickup of the disturbing field is minimum.

Warning: When you service an a-c/d-c receiver whose chassis connects to one side of the power line, use an isolation transformer between the power line and the receiver line input to keep the chassis from being hot. If a hot radio chassis is connected to the ground terminal of an oscilloscope or other piece of test equipment, the case of the test equipment will become hot, too. If you should contact the hot case of either the hot chassis or the instrument and some earth point, like the metal plate over a power outlet, you will suffer a severe shock.

When you service an a-c/d-c receiver that has a floating ground, connect the test instrument (excepting d-c voltmeter) ground leads to the chassis, not to the floating ground or B— point. Since one side of the power line connects to the B— point, connection of the ground terminal of an instrument to this point will make the instrument case hot, introducing shock danger.